THE EXPLORATION OF A FOUR-PLATFORM STANDING SCALE IN THE APPLICATION OF MEASURING TEMPERAMENT IN BEEF CATTLE

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The exploration of a four-platform standing scale in the application of measuring temperament in beef cattle

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The Supervisory Committee certifies that this *disquisition* complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

To assess the validity of a four-platform standing scale (FPSS) to measure cattle temperament, calves were evaluated at weaning age with an objective four-platform standing scale (FPSS) and subjective methods of docility score, temperament score, and qualitative behavior assessment (QBA). The standard deviation of total weight on FPSS over time (SSD), SSD's coefficient of variation (CVSSD) and first principal component of QBA attributes (i.e., temperament index; TI) were used as additional measures. The final mixed model included fixed effects of date and sex, and random effect of calf. Estimates of heritability ($\hat{h}^2$) across all traits were 0.141 to 0.439, except for QBA attribute of attentive ($\hat{h}^2 = 0$). Phenotypic correlation (-0.006 to 0.299) and genetic correlation (-0.309 to 0.643) between FPSS and subjective methods indicated FPSS may provide a valid way to capture temperament, but further verification with more measurements will be necessary due to sample size in this project.

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

LIST OF ABBREVIATIONS

BTA..*Bos taurus* autosome

CVSSD..Coefficient of variation of SSD

DS ....Docility score

EBV..Estimates of breeding value

EDTA..Ethylenediaminetetraacetic acid

FPSS...Four-platform standing scale

ID ....Calf identification

PCA..Principal component analysis

QBA ....Qualitative behavior assessment

QTL..Quantitative trait loci

SAS ....Statistical analysis system

SD ....Standard deviation

SSD ....Standard deviation of total weight over time recorded by FPSS

TI...Temperament index

TS..Temperament score

LIST OF SYMBOLS

$\hat{h}^2$ ....Estimates of heritability

r...Pearson correlation coefficient

$\hat{\rho}$ ....Spearman rank correlation coefficient

P ....Probability value

LIST OF APPENDIX TABLES

CHAPTER 1. INTRODUCTION

Temperament, which is comprised of different behavioral characteristics such as shyness-boldness, exploration avoidance, activity, sociability and aggressiveness (Reale et al, 2007), has a considerable impact on working safety, animal productivity, health and welfare. In beef cattle, animal's behavioral response to human handing has been widely viewed as an indicator for temperament although some concerns still exist. The increased automation of process and herd size in present livestock production system has limited animal-farmer interactions (Raussi, 2003), as well as increased fearful and stressful events (Boissy et al., 2005). To reduce fearful and stressful events, measuring temperament in beef cattle has become industry-wide interest. Some traditional, well established methods have been widely used for measuring temperament in beef cattle, including restrained and non-restrained methods (Burrow, 1997). Non-restrained (e.g., pen score) methods measure an animal's response to human proximity in a defined field without restraint. Restrained (e.g., chute test and flight time) methods measure an animal's response to human proximity as well as the response to physical restraint when restrained in a handling chute (Haskell et al., 2014). Based on the different methods for quantifying temperament, both subjective and objective methods were developed with varying strengths and weaknesses. Subjective assessments (e.g., chute test and pen score), which quantified temperament with a qualitative scale based on observer's scoring, has been predominantly adapted in the past. It is generally inexpensive, consistent and easy to implement, which would be preferred if it can be effective in recognizing the differences between poor and good behavior (Burrow et al., 2000). Objective methods, which quantitatively determined temperament, were created in regards to time management and objectivity, such as exit velocity (Burrow et al., 1988), strain gauges (Schwartzkopf-Genswein et al., 1997) and movement-measuring-device

(Stookey et al., 1994; Sebastian et al., 2011). These methods are typically continuous, quantifiable and objective as they do not depend on human interpretation of animals (Sebastian et al., 2011). The concerns about these objective methods are the aspects of behavior actually measured as they often lack the ability of capturing the complexity of temperament (Randel et al., 2012). In addition, erroneous interpretations usually appeared if only subjective or objective methods are applied alone (Sant'Anna and Paranhos da Costa, 2013). In this project, a novel objective method using a four-platform standing scale (FPSS), which can record an animal's weight shift and degree of weight shift over time, was applied as well as three other subjective methods. The degree of animal's weight shift over time capture by this objective method (i.e., FPSS) is thought to be correlated with different aspects of temperament, where less movement while on the scale (i.e., less weight shifts over time) may indicate calm temperament. The objective of this study is to investigate the validity of the FPSS as a novel objective method of measuring temperament as well as increase understanding of actual behavioral attributes of temperament captured by FPSS.

CHAPTER 2. LITERATURE REVIEW

Temperament

Temperament was first described as the “behavior of cattle in the bail” by Tulloh (1961). Burrow (1997) altered this definition to define temperament as “the animal’s response to human handing”. Very little scientific research focused on temperament of cattle until the 1980s, even though producers regarded temperament as an important trait (Elder et al., 1980a, 1980b). Currently, temperament is of industry-wide interest as calmer cattle result in less stress on both cattle and humans (Grandin, 1989b), and typically result in more efficient production along with reduced costs due to health reasons (e.g., Burdick et al., 2011). In general, “good” temperament means calm animals and “poor” temperament typically means agitated or unruly animals, where the degree of difficulty in handling an animal is a routine way to measure temperament (Morris et al., 1994; Sebastian et al., 2011). This assumption only considers temperament as a reaction to the handler and ignores the animal’s reaction without human interaction (Sebastian et al., 2011). Lyons (1989) described temperament as a “dynamic attribute of an individual that modulates environmental influences on behavioral and physiological systems”, which constitutes an individual’s overall behavior, emotions and reactivity. Grignard (2000) stated that the reasons of differences in temperament are not solely due to the reaction to handlers, but also depend on social and environmental situations. These studies recognized that temperament is a complex trait, and can be influenced by different behaviors and cues. For example, Burrow (1997) described behaviors of escape, fearfulness, freezing, aggression and docility as attributes to animal temperament. Lyons (1989) described avoidance, alertness, boldness, hesitation and environmental surveillances as characters of animal temperament. Stricklin and Kautzscanavy (1984) used nervousness, quietness, excitability, individuality, libido, constitution and emotionality as the description of animal temperament. With these discoveries, many methods were created to measure animal temperament by capturing these behavioral characters.

Methods of measuring temperament

The temperament of beef cattle has been proven to be moderately heritable and respond to selection (Burrow, 1997; Gutierrez et al., 2008). A standardized test method for producers is desirable as it allows the quantification of temperament by scoring behavior for selection purposes. In 1961, Tulloh first scored temperament of beef cattle based on their behavior when handled in a crush with a head bail. To get a temperament score of each animal, which can effectively reflect the behavior under normal handling procedure, Hearnshaw (1979) modified Tulloh's method by increasing stimulus control, shortening measurement time, using multiple observers, and taking repeated measures. Seven behavioral responses (tail swishing, straining back, backward and forward movement, padding with the back feet in an attempt to escape, kicking, kneeling and jumping), which were scored from 0 to 5, were introduced in this research to indicate temperament. Fordyce (1982) developed a series of temperament tests (i.e., crush test and flight distance) to test temperament behavior in different handling situations. Fordyce's crush test rated animals' vigor of movement with a 7-point scale from stands quietly (1) to struggles violently (7). Grandin (1993) adjusted Fordyce's crush test to rank animals' temperament during handling in the chute, which is widely used today. Grandin (1993) utilized a 5-point scale instead of a 7-point scale by condensing score 6 and 7 of the crush test (Fordyce et al., 1982) into score 5 with the premise that a 7-point scale is difficult for evaluators to accurately differentiate. Burrow (1988) introduced flight speed to improve flight distance (Fordyce et al., 1982), where flight speed is a relatively safe and simple method that measures the time of an animal passing a set distance. This improvement was done because flight distance

(Fordyce et al., 1982) was considered dangerous to evaluators due to having to interact with animals as well as difficult to implement in a typical production setting.

Since this time, additional subjective and objective methods measuring temperament in cattle have been proposed. Examples of subjective measures include docility test (Le Neindre et al., 1995), chute test (Tier et al., 2001), qualitative behavior assessment (QBA; Sant'Anna and Paranhos da Costa, 2013), and temperament score (Sant'Anna and Paranhos da Costa, 2013). Subjective methods are scored by human observers, which allows the evaluators to observe and combine different attributes of temperament based on their interpretation into a single score. This approach takes advantage of their knowledge and familiarity with animals (Gosling, 1998; Meaghter, 2009; Sant'Anna and Paranhos da Costa, 2013), but some methods can cause danger to evaluators during scoring and may generate erroneous interpretations due to past experiences of evaluators. For example, zebu cattle with freezing behavior can be misinterpreted as calm temperament in a crush score test, but are actually exhibiting fear (Sant'Anna and Paranhos da Costa, 2013). These methods are also difficult to compare across studies because of the subjectivity of temperament by the observer (Manteca and Deag, 1993).

To eliminate the danger to evaluators and make comparison between different studies easier, objective approaches were introduced, such as movement-measuring-device (Stookey et al., 1994; Sebastian et al., 2011) and strain gauges (Schwartzkopf-Genswein et al., 1997). These methods are continuous, quantifiable and objective as they do not require human interpretation of animals (Sebastian et al., 2011). There are concerns about which aspects of temperament are being measured in these approaches, as they often lack the ability to capture the complexity of temperament (Randel et al., 2012). In addition, using these objective or subjective methods alone may also cause erroneous interpretations (Sant'Anna and Paranhos da Costa, 2013). Due to this, utilizing both subjective and objective methods are expected to enhance our understanding of aspects in temperament that objective methods may be identifying.

Effects of experiences on temperament

A repeated stimulation can generate habituation, which will result in a decreased response to the repeated stimulation by the learning process (Bouton, 2007). The previous handling experience and acclimation to human handling are an important consideration as regards to beef cattle temperament (Jones, 2013). In methods involving human interactions, Hemsworth et al. (1996) found cattle with positive handling experience allowed the experimenter to approach more quickly and spent more time interacting with the experimenter, which indicated a decreased fear to human interaction. Haskell et al. (2014) proposed that the heritability estimates of temperament decreased with age at evaluation, which may be due to the habituation of handling and decreases genetic and phenotypic variation of temperament in the population. This would also mean that the selection pressure that can be applied on temperament would be impacted as well. Conversely, an acclimation procedure was reported to cause no changes in temperament scores (Arthington et al., 2013). A conflicting result of decreased exit velocity and increased temperament score was reported in an experiment of testing the effects of acclimation to handling on *Bos taurus* cattle (Cooke et al., 2015). Bulls with excitable temperaments were found to become calmer over time after continual exposure to humans (Lockwood et al., 2015). Habituation of beef or dairy cattle has been proven to develop effectively in their early life with positive handling experience, which resulted in calmer cattle with human handling (Bovin et al., 1992). Fordyce et al. (1985) addressed that cattle with handling experience before 18 months of age were easier to handle than non-handled animals.

Furthermore, Bovin et al. (1994) stated that animals reared indoors are usually more docile than range reared animals.

Genetics and temperament

Heritability. Understanding the genetic variation of temperament is key to achieving genetic improvement via selection. Estimates of heritability, which defines the proportion of phenotype variation accounted by additive gene effects, can provide insight into the expected selection response of a given trait due to additive genetic control for that trait (Haskell et al., 2014). A large number of studies have shown temperament with a wide range of heritability estimates (i.e., $\hat{h}^2$ = 0.02 to 0.70), where differences among estimates of heritability may be due to different methodologies or breeds (Haskell et al., 2014). Mostly, heritability of objective measures are higher than subjective scores (Burrow and Corbet, 1999; Benhajali et al., 2010). However, the unweighted mean and range in estimates of heritability for subjective and objective measures are very similar, where subjective measures average $\hat{h}^2 = 0.24$ (range: 0.03 to 0.67) and objective measures average $\hat{h}^2 = 0.36$ (range: 0.05 to 0.7; Haskell et al., 2014). Similarly, Burrow (1997) found that the estimates of heritability were similar under different methodologies (non-restrained test is $\hat{h}^2 = 0.36$ and restrained test is $\hat{h}^2 = 0.23$).

Breed and sex differences. The phenotype variations between different breeds under the same management environment implies temperament traits are under genetic control. *Bos taurus* cattle has been reported to be more docile in handling than *Bos indicus* cattle (Hearnshaw et al., 1979; Becker and Lobato, 1997; Buchenauer, 1999; Burrow, 2001). Early studies found Angus cattle have more excitable temperaments than Hereford (Stricklin et al., 1980), however a recent study has shown that this difference may have been eliminated due to selection (Gauly et al., 2001). Fordyce et al. (1988) found Shorthorn cattle have good temperament compared to

Brahman bloodlines in restrained tests. German Angus were reported to be more easily handled compared to Simmental cattle under a restrained and separation test (Gauly et al., 2001). Hoppe et al. (2010) reported that continental French breeds (i.e., Charolais and Limousin) showed more intensive responses to restraint than British breeds (Angus and Hereford). Furthermore, the sex of the animal may also contribute to temperament traits as cows were reported to have higher temperament scores than steers (Voisinet et al., 2003; Schutz et al., 2012). Similarly, Riley et al. (2014) found heifers have more excitable temperaments than both bulls and steers, where bulls showed the lowest mean of overall temperament score.

Genetic control. Quantitative trait loci (QTL) have been found to contribute to a number of behavioral traits both in dairy and beef cattle (Spelman et al., 1999; Schmutz et al., 2001; Hiendleder et al., 2003; Wegenhoft, 2005; Boldt, 2008; Esmailizadeh et al., 2007; Gutierrez-Gil et al., 2008). QTLs on bovine chromosomes (BTA) 1, 8, 9, 16 and 29 were identified to be associated with behavioral traits across different studies. Candidate gene *DRD4* on BTA 29 is a proven receptor of dopamine participating in behavioral attributes of curiosity and novelty seeking (Glenske et al., 2011). This gene has been reported to be associated with the regulation of temperament (Rubenstein et al., 1997; Glenske et al., 2011). Hulsman Hanna et al. (2014) also found a correlation between response under stimulus of social separation and a gene controlling sodium ion transport.

Temperament in production

Animal welfare. Hughes (1976) defined animal welfare as “A state of complete mental and physical health, where the animal is in harmony with its environment.” Improvement of animal welfare has an important influence in beef cattle production, as modern intensive or semi-intensive livestock production systems have limited the interaction between animals and farmers, which contributes to fearful events (Friedrich et al., 2015). Calmer animals under stimuli of novel subjects or isolation from group mates have been reported to adapt better to modern intensive livestock production systems than excitable animals (Kilgour et al., 2006; Gibbons et al., 2009b). Burrow (1997) proposed that the decrease of stress events can be achieved by temperament improvement. Temperament is also reported to influence the ability of animal to cope with environmental stimuli (Ruis et al., 2002). It is important to understand the relationship between certain handling tests and animal personalities as it will help establish the link between temperament and welfare, which can be applied to increase animal welfare by improvement of temperament (Kilgour et al., 2006).

Animal production. Importance of temperament to production attributes has been investigated by many researchers. Sant'Anna et al. (2012) proposed that animals with fast speeds had lower weights (e.g., negative correlation between weaning weight of Nellore cattle and temperament measurements). Reinhardt et al. (2009) also reported that cattle with more excitable chute score were more likely to have a lower bodyweight. Growth rate or daily gain, which accurately indicates the bodyweight variation, has also been investigated for a relationship between temperament and growth rate (Haskell et al., 2014). Cattle with excitable temperament have been reported to grow more slowly based on the opposed phenotype correlation between growth rate and temperament (Voisinet et al., 1997a; Fell et al., 1999; Petherick et al., 2002; Reinhardt et al., 2009; Turner et al., 2011; Sant'Anna et al., 2012). Similar phenotypic correlation was found between feed efficiency and flight speed (Petherick et al., 2002; Café et al., 2011b). Excitable cattle showed phenotypic correlation with lower carcass weights in both *Bos taurus* and *Bos indicus* cattle (Burrow and Dillon, 1997; Nkrumah et al., 2007; Reinhardt et al., 2009; Café et al., 2011b). Temperament traits were also found to have negative correlation with reproductive characteristics by some studies. Excitable bulls were reported to have smaller scrotal circumference (Burrow, 2001; Barrozo et al., 2012), which is an indicator of reproductive performance. Similarly, docile heifers were found to be younger at puberty and have higher fertility as measured through calving rate (Phocas et al., 2006). Animal stress in transportation and handling before pre-slaughter period has substantial influences as it will lead to a reduction of glycogen (associated with meat quality) in muscle, thereby causing tough meat with the low level of glycogen (Ashmore et al., 1973; Maltin et al., 2003). A number of temperament measurements have proven that excitable animals increased shear force of meat and resulted in lower tenderness scores compared to calmer animals (Reverter et al., 2003; Café et al., 2011b; Hall et al., 2011).

As to these research results, defined temperament traits in cattle have already been measured and the heritability of these traits have been calculated. Some favorable genetic correlation between temperament and animal production has been found, which suggests genetic selection for temperament is applicable. However, a temperament measure is not often included in the selection indexes as there is a lack of complete information about the genetic and phenotypic correlation between temperament and all productive parameters (Haskell et al., 2014). To understand the dimension of temperament traits and improve the accuracy of temperament measures without including the evaluator’s bias, in this research, a novel quantitative method of FPSS was tested by comparing with three other subjective methods.

CHAPTER 3. MATERIAL AND METHODS

Animals

Data used in this study was collected between September 2014 and October 2015 at North Dakota State University Central Grasslands Research Extension Center (CGREC) near Streeter, North Dakota using calves at weaning age (n = 806). The CGREC cow herd consists of approximately 425 Angus-based females (mature cows and heifers) that are bred to Angus or Hereford bulls. Calves born in 2014 (n = 423) were produced by breeding these cows and heifers to purebred Angus bulls. Dams born prior to 2012 had unknown breed makeup, therefore calves were considered ½ Angus ½ Unknown for breed type (n = 342). Dams born in 2012 were known to be ½ Angus ½ Unknown due to sire and dam breed type, which produced calves known to be ¾ Angus ¼ Unknown (n = 81). In 2015, 383 calves were produced by breeding dams to purebred Hereford and Angus bulls. Of these calves, 259 were produced by cows born before 2012 with unknown breed types creating ½ Hereford ½ Unknown calves (n = 14) and ½ Angus ½ Unknown calves (n = 245). The remaining calves were from dams born in 2012 and 2013 that were known to be ½ Angus ½ Unknown, which produced 124 calves of ½ Hereford ¼ Angus ¼ Unknown type (n = 32) and ¾ Angus ¼ Unknown (n = 92). All available calves produced in 2014 and 2015 from this herd were used in temperament evaluations at weaning.

Blood collection

A later study will investigate the use of genomic data with temperament scores collected, therefore blood was collected using jugular venipuncture for white blood cell pellet and DNA extraction using two 10 mL EDTA BD-vacutainer blood tubes. Blood was collected following docility score, but prior to temperament and qualitative behavior assessment (QBA) scoring, therefore, there was concern of blood draw effect on measures of temperament. To investigate this, the calves were randomly split into two groups in the first year, where one half of the animals were scored with those three methods (FPSS, temperament score, and QBA) after blood collection and the other half of animals were scored with all temperament methods prior to blood drawing. The preliminary statistical analysis of first year data showed that blood collection was not a significant effect ($P \geq 0.072$, Table 1). Least squares means of blood drawn within date of evaluation (drawn before or after evaluation within a day) shown non-significant effect across all traits (Appendix Table 1), therefore, it was not continued in the second year. All procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee.

Table 1. *P*-values of blood drawn nested within date of evaluation effect for TS, TI, SSD, CVSSD and QBA attributes[1]

Measures	**Blood drawn (date of evaluation)**
TS	0.187
TI	0.255
SSD	0.189
CVSSD	0.214
Active	0.338
Relaxed	0.200
Fearful	0.424
Agitated	0.072
Calm	0.176
Attentive	0.196
Positively occupied	0.405
Curious	0.616
Irritated	0.434
Apathetic	0.880
Happy	0.336
Distressed	0.328

[1] TS: temperament score, TI: temperament index, SSD: standard deviation of four-platform standing scale data, CVSSD: coefficient of variation based on SSD, QBA: Qualitative Behavior Assessments. *P-value* > 0.05 is non-significant.

Temperament assessment

On evaluation day, calves were moved through the working pens to the evaluation areas before being sorted for management purposes (Figure 1). Six evaluators were randomly assigned to 2 of 3 subjective scoring methods (4 evaluators per method). This approach is meant to reduce the evaluator's stress and further bias due to scoring a single animal with multiple scales. Upon entering the working pens, calves first entered the silencer chute (Moly Manufacturing, Lorraine, KS) and first evaluated for docility score (Table 2), then weaning weight was recorded. Following weaning weight collection, the animal was fully caught and blood samples were collected. The calf was then moved to the four-platform standing scale (FPSS; Pacific Industrial Scale, British Columbia, Canada), where data was collected on each quadrant with a rubber mat placed on top (approximately 1.22 m wide by 2.44 m long) to improve traction and comfort for the animal (Figure 2). An worker controlled the computer and software connected to FPSS to record the weight shifts on each foot while calves were standing evenly without movement restriction on FPSS for at least 45 seconds and calf was not released until the outside testing area was clear from the previous calf. Following FPSS, calves were released to a working pen (outside testing area) for temperament score (TS) and QBA evaluation (Tables 3 and 4), where evaluators observed their behavior and interaction with the worker present from the observation area (Figure 1). Within the working pen used for temperament and QBA scoring, a worker was present to interact with the animal so that evaluators can assess the different aspects of these subjective scoring methods. Four evaluators scored each animal with a scoring sheet, which included a list of these 12 attributes (Table 4) and each attribute followed by a 136 mm horizontal line, where the far left side of the line indicates no expression and the far right side of the line indicates full expression of this attribute. The length of this scoring line in this project is

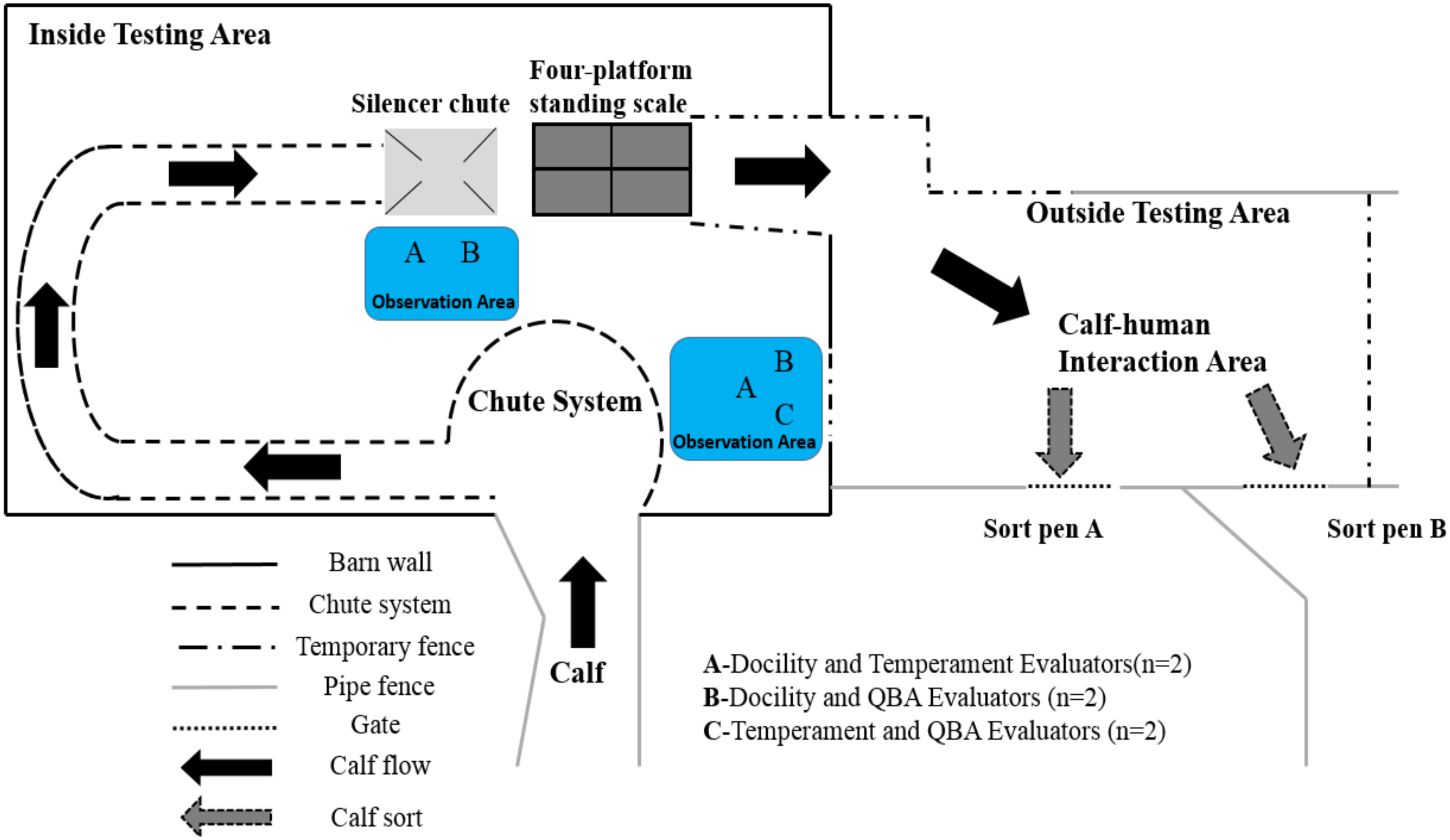

Figure 1. Illustration of processing calves for temperament scoring of docility score (silencer chute), four-platform standing scale, temperament score (outside testing area) and qualitative behavior assessment (outside testing area) at the North Dakota State University Central Grasslands Research Extension Center. Blood was also collected at the silencer chute following docility scoring.

Table 2. Description of Docility score for temperament evaluation[1]

Score value	Description or qualification for that value
1	Docile. Mild disposition. Gentle and easily handled. Stands and moves slowly during processing. Undisturbed, settled, somewhat dull. Does not pull on headgate when in chute. Exits chute calmly.
2	Restless. Quieter than average, but may be stubborn during processing. May try to back out of chute or pull back on headgate. Some flicking of tail. Exits chute promptly.
3	Nervous. Typical temperament is manageable, but nervous and impatient. A moderate among of struggling, movement and tail flicking. Repeated pushing and pulling headgate. Exits chute briskly.
4	Flighty (Wild). Jumpy and out of control, quivers and struggles violently. May bellow and froth at the mouth. Frantically runs fence line and may jump when penned individually. Exhibits long flight distance and exits chute wildly.
5	Aggressive. May be similar to Score 4, but with added aggressive behavior, fearfulness, extreme agitation, and continuous movement which may include jumping and bellowing while in chute. Exits chute frantically and may exhibit attack behavior when handled alone.
6	Very Aggressive. Extremely aggressive temperament. Thrashes about or attacks wildly when confined in small, tight places. Pronounced attack behavior.

[1] Scale is based on description by Beef Improvement Federation (2010), where the head is restrained but the body of the animal is not.

different with Sant'Anna and Paranhos da Costa (2013) experiment, which is 126 mm. However, there is no concern about the small difference, as 10 mm is not expected to cause a significant variation. Once all evaluators were finished, calves were sorted into a holding pen based on management needs. The working environment was controlled to reduce the influences to human interaction besides the specific areas of handling for evaluation.

Data entry and audit

Temperament data of all measurements (n = 16) were processed and audited before using in further analyses. Scores of docility and temperament tests were entered and audited based on the records of scale sheets. For QBA data, distance from the far left side of each horizontal line to the evaluator's mark, which indicates the score of each attribute, was measured with an

Figure 2. Photographs of the four-platform standing scale (FPSS) being transported and in use during data collection.

Table 3. Description of Temperament score for temperament evaluation[1]

Score value	Description or qualification for that value
1	animal walks slowly, allowing close proximity to the observer
2	trots or runs for a few seconds, allowing a moderate proximity to the observer
3	exclude
4	runs during the entire observation time, looks for an escape with constant movement of the tail, and does not allow approximation
5	runs during the entire time of assessment, jumps against fences and obstacles, and tries to attach the observer

[1] Scale is following the protocol used by Sant'Anna and Paranhos da Costa (2013), where score 3 was excluded to avoid evaluators choosing an intermediate score.

Table 4. Description of Qualitative Behavior Assessment (QBA) for temperament evaluation[1]

Attribute	Description or qualification for that value
Active	quick in physical movement (lively); disposed to action (energetic)
Relaxed	set or being at rest or at ease
Fearful	full of fear
Agitated	disturbed, excited, angered
Calm	tranquil, peaceful
Attentive	watching something carefully; paying attention
Positively occupied	NA
Curious	showing a desire to learn or know more about something or someone
Irritated	being bothered, irked, aggravated, annoyed
Apathetic	showing little or no feeling or emotion
Happy	showing feelings of pleasure and enjoyment
Distressed	showing extreme unhappiness or pain

[1] Scale is following the QBA protocol of Sant'Anna and Paranhos da Costa (2013), where each attribute is followed by a 136 mm horizontal line, which is different with 126 mm in the protocol.

electronic digital caliper (General Tools & Instruments, New York, USA). Based on the data records, records for 9 calves were dropped from 2014 data because 3 calves were missing records from the FPSS, 3 calves' FPSS records were not complete and reasonable, and 2 steers' castration were not successful, leaving them as bulls, which could potentially bias results. For 2015 data, records of 10 calves were excluded across all traits because 6 calves' FPSS records were not complete and reasonable, 3 calves were missing sex records, and 1 calf (calf identification (ID) 14138) was recorded as dead at birth, but a calf with this ID had temperament records, and was assumed to be recorded in error. The final number of calves across both years for all traits used for analyses was 787 (n = 414 in 2014; n = 373 in 2015). Once temperament scores were entered and audited, average temperament score across evaluators of each subjective method (TS, DS and QBA attributes) was calculated for further analyses in this project.

FPSS Measures. The standard deviation of the FPSS data (SSD) was calculated following 3 steps:

1. Within each animal's data file, the ideal data point (start point) when the animal was completely standing on the scale was located (see Figure 3 for how this point was identified).

2. The number of observations after this start point (including the start point) was counted for each animal.

3. The total number of observations available across animals were compared and the ideal number of observations was set as the number of data points for calculating mean and SSD across animals. Priority was given to including as many records and animals as possible as long as the data was reliable.

There is a concern that the actual weight of the animal may bias the SSD calculated, given that larger animals may naturally have larger SSD, regardless of temperament. Therefore, the coefficient of variation of the SSD (CVSSD) was calculated as the SSD divided by the mean total weight over the same FPSS scale records for a given animal. This will provide a unit-less measure that is generalized and comparable regardless of the animal's actual weaning weight. Both SSD and CVSSD were used as measures of temperament for this project.

Statistical analysis

Correlation between the 12 attributes of QBA were summarized with both Pearson and Spearman Rank correlation coefficients in SAS (SAS Institute, Inc., Cary, NC). Following Sant'Anna and Paranhos da Costa (2013), an additional temperament score (temperament index,

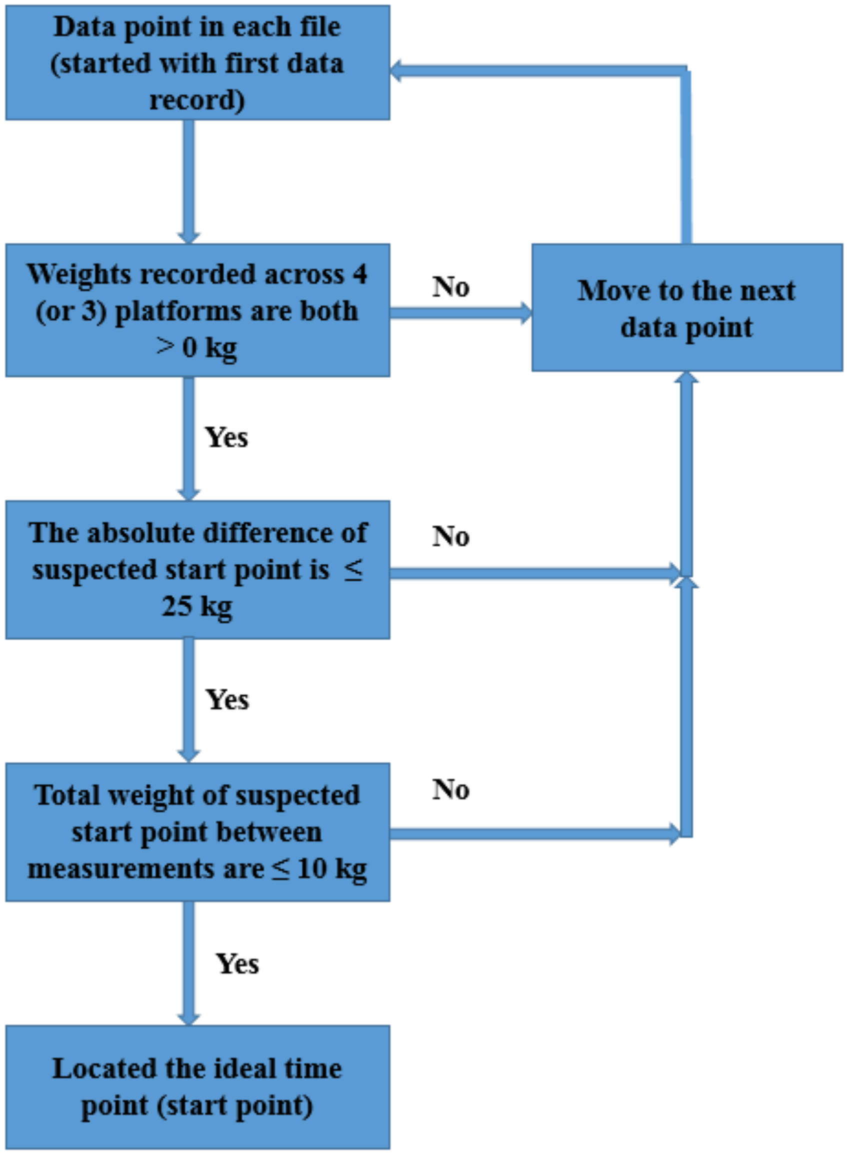

Figure 3. Procedure of locating start point for records from the four-platform standing scale to determine ideal number of records in calculating the standard deviation of records for a given animal. Absolute difference indicates absolute weight difference between total weight recorded by FPSS and weaning weight from the silencer chute. Total weight of suspected start point between measurements are calculated within suspected start point and 5 following records.

TI) was generated with QBA data by using a principal component analysis. The principal component analysis was conducted using principal component procedure in SAS (SAS Institute, Inc., Cary, NC), where the first principal component was used as TI following Sant'Anna and Paranhos da Costa (2013) and recommendations by Jolliffe (2002).

Measures of central tendency and variability across the 17 traits were summarized in SAS (SAS Institute, Inc., Cary, NC) to describe the basic features of the data. The influences of systematic environmental fixed effects (e.g., date of evaluation, sex and breed types), genetic random effects (e.g., animal), as well as fixed covariate of sequence nested within date of evaluation were examined by analyzing each trait (SSD, CVSSD, TS, DS, QBA attributes, TI) independently in SAS (SAS Institute, Inc., Cary, NC) with mixed model procedures. The final statistical model was used in ASReml (Gilmour et al., 2015) by analyzing each trait independently (n = 17, univariate analysis) using pedigree to estimate breeding values (EBV) and heritability ($\hat{h}^2$).

To characterize association between TI, SSD, and CVSSD with the two subjective methods (i.e., DS and TS), each trait was modeled as a function of subjective measurements with other effects in the final statistical model, where DS and TS were modeled as a fixed effects independently of each other. As DS and TS were averages of the four evaluator scores, categories were assigned to relate back to the original scoring system (Table 5) and then used as a fixed effect for TI, SSD and CVSSD to conduct least squares means comparison with Tukey-Kramer adjustment. Furthermore, four temperament groups (i.e., I, II, III and IV) were defined based on the first and second principal component (similar to Sant'Anna and Paranhos da Costa, 2013), where each animal was assigned to a temperament group. This group assignment was used in the final model as a fixed effect for the 12 QBA attributes, TS, DS, SSD and CVSSD to compare least squares means based on groups, where experiment-wise error rate was controlled by Tukey-Kramer adjustment.

Table 5. Description of criteria for assigning new categories for DS and TS[1]

Category	DS	TS
1	< 1.5	< 1.5
2	≥ 1.5, < 2.5	≥ 1.5, < 2.5
3	≥ 2.5, < 3.5	-
4	≥ 3.5, < 4.5	≥ 2.5, < 4.5
5	≥ 4.5, < 5.5	≥ 4.5
6	≥ 5.5	-

[1] DS: docility score, TS: temperament score. "-" indicates not available.

Genetic and phenotypic correlations among select pairs of traits, which can provide a direction of the correlation of the FPSS measures with subjective measures, were estimated in ASReml (Gilmour et al., 2015) by bivariate analysis with a traditional animal model. Bivariate analyses included comparison between FPSS measures (SSD and CVSSD) and three subjective methods (DS, TS, and TI), as well as QBA attributes. Bivariate analysis between CVSSD and SSD was applied to recognize the correlation between these two methods. Seed values for additive genetic variances and covariances as well as residual variances were used based on univariate estimates. The comparison between FPSS measures and three subjective methods was applied to test the validity of FPSS measures for understanding temperament. Comparison with QBA attributes was also expected to investigate the actual characters of temperament captured by FPSS. The genotypic correlation between traits where one or both traits had a heritability estimate of zero was not compared as it will cause the correlation coefficient to be theoretically undefined (Akesson et al., 2008).

Pearson and Spearman Rank correlation coefficients of estimated breeding values (EBV) from univariate analyses were calculated using the correlation procedure in SAS (SAS Institute, Inc., Cary, NC) to understand general similarities and differences between EBV of each pair of traits (a.k.a. univariate approach to genetic correlation). Critical correlation coefficient (r) for interpretation of Spearman Rank correlation followed the protocol of Hopkins (2000): $r < 0.1$, trivial correlation; $0.1 < r < 0.3$, slight correlation; $0.3 < r < 0.5$, moderate correlation; $0.5 < r < 0.7$, substantial or large correlation; and $r > 0.7$, very large correlation as general markers for interpretations. Quartile ranking comparison similar to Hulsman Hanna et al. (2014) were conducted to further characterize similarities and differences among EBV between each pair of traits. Each trait (n = 17) was assigned to quartiles based on EBV independently and respectively ranked for each trait (i.e., ranked from desirable to undesirable). Once assigned across all traits, quartile assignment comparison was conducted in Microsoft Excel 2013 for a given pair of traits to determine the magnitude of change. The number and percentage of individuals with EBV based on the number of quartile changes between two traits (0, 1, 2, or 3 quartiles) were compared to find the similarities and differences among EBV for a given pair of traits.

CHAPTER 4. RESULTS AND DISCUSSION

Principal component analysis

Description of QBA measurements. Descriptive statistics of 12 QBA attributes generated for each year and across years are reported in Table 6. Within each attribute, some attributes (i.e., relaxed and calm) showed numerical differences between the 2 years. Compared to the first year (2014), the descriptive statistics for the second year (2015) showed numerically lower means for attributes of relaxed, calm, attentive and active, as well as numerically higher means for attributes of fearful, agitated, irritated and distressed.

Differences within each attribute between years may be due to variations such as population size differences, evaluator bias and population variation. However, these variations are not likely to cause a significant bias in the overall data across the two years. Some attributes associated with positive temperament (i.e., relaxed, calm and attentive) that received higher means may indicate animals included in this project have relatively good temperament on average, which is quite different with results from Sant'Anna and Paranhos da Costa (2013). They reported attributes of attentive, active and calm with higher means, which included two extreme attributes of temperament (i.e., active and calm) that indicate cattle in their project show more active characteristics of temperament than ours. However, this difference was expected as cattle in our project (*Bos taurus*) are different from the Nellore cattle (*Bos indicus*) utilized by Sant'Anna and Paranhos da Costa (2013). This difference agrees with research that has found *Bos indicus* cattle are more temperamental or excitable than *Bos taurus* cattle (Elder et al., 1980; Fordyce et al., 1988). Attributes such as fearful, agitated, irritated and distressed had lower numerical means compared to other QBA attributes measured, which may indicate that the majority of the animals did not express negative temperament attributes to a high degree.

Table 6. Descriptive statistics for the 12 behavioral attributes of QBA[1]

QBA	2014			2015			Overall		
	Mean ± SD	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**
Active	43.428 ± 14.154	17.820	104.560	57.331 ± 24.052	6.190	122.490	50.017 ± 20.671	6.190	122.490
Relaxed	88.630 ± 18.299	27.110	125.940	54.970 ± 30.443	2.050	131.800	72.677 ± 29.957	2.050	131.800
Fearful	15.226 ± 9.926	2.110	73.780	23.489 ± 15.972	1.280	91.730	19.142 ± 13.768	1.280	91.730
Agitated	21.538 ± 1 2.869	3.970	84.920	31.671 ± 22.478	0.830	109.430	26.341 ± 18.756	0.830	109.430
Calm	94.196 ± 18.146	26.320	132.060	58.704 ± 32.095	2.430	130.630	77.375 ± 31.225	2.430	132.060
Attentive	70.724 ± 13.643	28.220	109.850	37.694 ± 15.349	5.310	112.310	55.069 ± 21.947	5.310	112.310
Positively occupied	51.679 ± 12.056	23.550	91.030	15.043 ± 9.266	0.940	61.910	34.315 ± 21.262	0.940	91.030
Curious	50.839 ± 14.522	12.500	99.180	14.268 ± 10.783	0.000	73.490	33.506 ± 22.354	0.000	99.180
Irritated	21.286 ± 13.483	1.900	76.840	20.841 ± 20.282	0.000	104.330	21.075 ± 17.037	0.000	104.330
Apathetic	59.781 ± 13.939	21.170	108.900	35.130 ± 13.538	3.110	93.220	48.097 ± 18.453	3.110	108.900
Happy	57.313 ± 13.099	10.610	93.910	9.544 ± 9.883	0.000	54.000	34.673 ± 26.571	0.000	93.910
Distressed	14.923 ± 11.341	2.680	77.380	13.072 ± 14.777	0.000	90.150	14.046 ± 13.107	0.000	90.150

[1] QBA refers to Qualitative Behavior Assessment. Number of observation is 414 calves in 2014, 373 calves in 2015 and 787 calves across the two years.

The correlation between the 12 QBA attributes were calculated with Pearson ($\hat{\rho}$) and Spearman Rank (r) correlation coefficients, where results are summarized in Table 7. Both Pearson and Spearman Rank correlation coefficients illustrate that high correlation exists among the 12 attributes, which was expected. For example, attribute of active is negatively correlated to attributes of relaxed (Pearson $\hat{\rho}$ = -0.815, Spearman Rank r = -0.791) and calm (Pearson $\hat{\rho}$ = -0.811, Spearman Rank r = -0.784). Furthermore, positive correlations of active with attributes of fearful (Pearson $\hat{\rho}$ = 0.777, Spearman Rank r = 0.762) and agitated (Pearson $\hat{\rho}$ = 0.79, Spearman Rank r = 0.728) were identified. These strong correlation coefficients (i.e., < -0.70 or > 0.70) suggests animal with higher scores for active will have lower scores for relaxed and calm, as well as higher scores for fearful and agitated. These correlations were expected due to the different characteristics of these attributes. For example, attributes of active, fearful and agitated are associated with a lively character, which is significantly different with attributes of relaxed and calm that are related to a peaceful character. Some non-significant correlations were found between QBA attributes (e.g., attentive with active and fearful), however, all attributes were significantly correlated with at least 9 of the 11 other attributes (Table 7). Considering that the majority of all attributes are highly correlated, principal component analysis (PCA) was used to combined these attributes to get a few principal components (PC), which maximize the variance within each PC based on covariance or correlation coefficients (Jolliffe, 2002).

Principal component analysis with QBA measures. The PCA analysis for the average of each QBA attributes resulted in 12 principal components, where the eigenvalues are reported in Table 8. The eigenvalues indicate the amount of the variation explained by each principal component (PC), where eigenvalues above a value of 1 indicates a high proportion of variation in the data accounted for (i.e., Kaiser's criterion; Kaiser, 1960; Jolliffe, 2002). This is also

Table 7. Pearson and Spearman Rank correlation coefficients for pairs of QBA attributes[1]

	Active	Relaxed	Fearful	Agitated	Calm	Attentive	Positively occupied	Curious	Irritated	Apathetic	Happy	Distressed
Active		-0.815	0.777	0.790	-0.811	-	-0.367	-0.368	0.671	-0.598	-0.432	0.477
Relaxed	-0.791		-0.776	-0.794	0.955	0.202	0.563	0.550	-0.605	0.744	0.622	-0.452
Fearful	0.762	-0.798		0.872	-0.782	-	-0.298	-0.308	0.784	-0.581	-0.356	0.634
Agitated	0.728	-0.783	0.835		-0.800	0.097	-0.268	-0.292	0.820	-0.593	-0.342	0.655
Calm	-0.784	0.944	-0.792	-0.779		0.220	0.585	0.574	-0.611	0.765	0.631	-0.449
Attentive	-	0.228	-	0.112	0.242		0.751	0.707	0.331	0.346	0.711	0.312
Positively occupied	-0.368	0.558	-0.290	-0.227	0.577	0.749		0.852	-	0.678	0.914	0.097
Curious	-0.362	0.542	-0.295	-0.245	0.565	0.716	0.849		-	0.610	0.852	-
Irritated	0.609	-0.559	0.710	0.753	-0.561	0.397	0.089	-		-0.406	-	0.838
Apathetic	-0.594	0.748	-0.572	-0.546	0.766	0.405	0.696	0.646	-0.290		0.714	-0.273
Happy	-0.431	0.622	-0.357	-0.32	0.629	0.685	0.894	0.843	-	0.722		-
Distressed	0.441	-0.409	0.566	0.57	-0.413	0.384	0.174	0.131	0.823	-0.153	0.124	

[1] All reported correlations are significant ($P \leq 0.05$), where "-" cells indicate non-significant ($P > 0.05$) correlations. Correlations above the diagonal indicate Pearson correlation coefficients, and Spearman Rank correlation coefficients are below the diagonal. QBA refers to Qualitative Behavior Assessment.

Table 8. Eigenvalues and proportion of variation accounted for by principal components from analysis with 12 Qualitative Behavior Assessment attributes

Principal component	Eigenvalue	Proportion[1]	Cumulative[2]
1	6.746	0.562	0.562
2	3.321	0.277	0.839
3	0.502	0.042	0.881
4	0.334	0.028	0.909
5	0.216	0.018	0.927
6	0.209	0.017	0.944
7	0.183	0.015	0.959
8	0.144	0.012	0.971
9	0.125	0.010	0.982
10	0.098	0.008	0.990
11	0.081	0.007	0.996
12	0.043	0.004	1.000

[1] Proportion indicates the proportion of variation accounted for by each principal component.
[2] Cumulative is obtained by adding successive proportions.

supported by the scree test (Cattell, 1966; Figure 4), which plots the eigenvalues based on PC. The scree plot illustrates the rate of change in the magnitude of the eigenvalues for the PC, where the PCs following the elbow bend of the scree plot will not account for significant variation (e.g., PC 3 through 12 in this case) and are considered to indicate the maximum number of PC to extract. According to scree plot, 3 components would be retained (Figure 4). However, the third PC was not retained as its eigenvalue was much less than 1 (Kaiser, 1960; Fernandez, 2003). The first two PCs were retained in this study, which is same with findings of Sant'Anna and Paranhos da Costa (2013). The first two PCs in this study, however, accounted for 83.9% of the total variation, which is greater than 59.68% reported by Sant'Anna and Paranhos da Costa (2013). This difference may be due to the improvement of experiment design in this project, such as using the average score across 4 evaluators for each attribute to decrease observer's bias instead of only one evaluator as applied by Sant'Anna and Paranhos da Costa (2013). Additionally, it could be due to the breed differences between these two studies, as *Bos indicus* used by Sant'Anna and Paranhos da Costa (2013) are known for different behavioral reactions under a

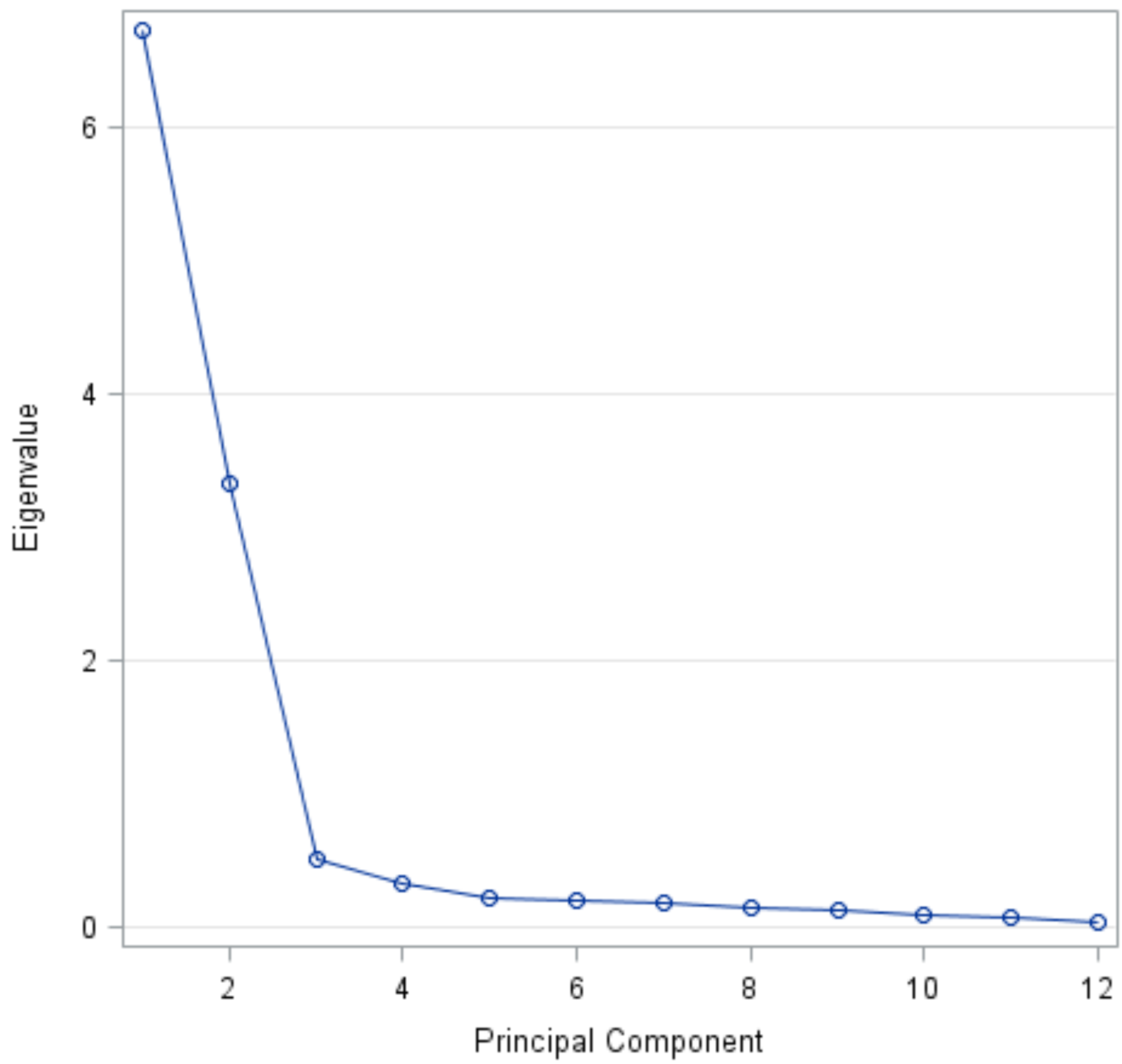

Figure 4. Scree plot based on principal components and eigenvalues for 12 Qualitative Behavior Assessment attributes. Eigenvalues less than 1 indicate principal components that account for non-significant variation.

fearful situation, such as flight, agitation and "freeze" (Burrow and Corbet, 1999; Sant'Anna and Paranhos da Costa, 2013). These differences of behavioral reactions under the same stressful situation may confuse the evaluator and cause evaluation errors, causing differences seen in this project.

Factor loading, which illustrates the correlation between QBA attributes and principle component 1 (PC1) and 2 (PC2), are presented in Table 9. Loading plots of QBA attributes in

Table 9. Factor loadings of Qualitative Behavior Assessment (QBA) attributes in principle component 1 (PC1) and 2 (PC2)[1]

QBA attribute	PC1	PC2
Active	-0.840	0.252
Relaxed	0.939	-0.049
Fearful	-0.838	0.377
Agitated	-0.844	0.413
Calm	0.949	-0.034
Attentive	0.285	0.847
Positively occupied	0.662	0.690
Curious	0.654	0.638
Irritated	-0.660	0.670
Apathetic	0.832	0.202
Happy	0.716	0.632
Distressed	-0.506	0.671

[1] Factor loading refers to the elements in the loading matrix that indicates the correlation between QBA attributes and principal component. Factor loadings = Eigenvectors * $\sqrt{\text{Eigenvalues}}$.

PC1 and PC2 are shown in Figure 5. The scores of QBA attributes based on PC1 is used as temperament index (TI) following Sant'Anna and Paranhos da Costa (2013) to produce a single temperament variable to account for the most variation in the QBA attributes.

The first principal component explains over 50% of the total variation in QBA dataset (Table 8) and has strong positive loadings (Table 9) for attributes of calm, relaxed, apathetic, happy, positively occupied and curious, which are all attributes that are related to good temperament. It also has strong negative loadings for attributes of agitated, active, fearful, irritated and distressed, which are typically related to bad temperament. The PC2 has high positive loadings for attributes of attentive, positively occupied, distressed, irritated, curious, and happy, as well as minimal negative loadings for relaxed and calm. Attributes of calm and relaxed, as well as attributes of agitated and active, have significant influences on TI (PC1), which indicates TI can reflect extreme behavioral reactions of calm and agitated. This means TI can be used as a measurement of calm and agitated, and this is agreement with other studies that

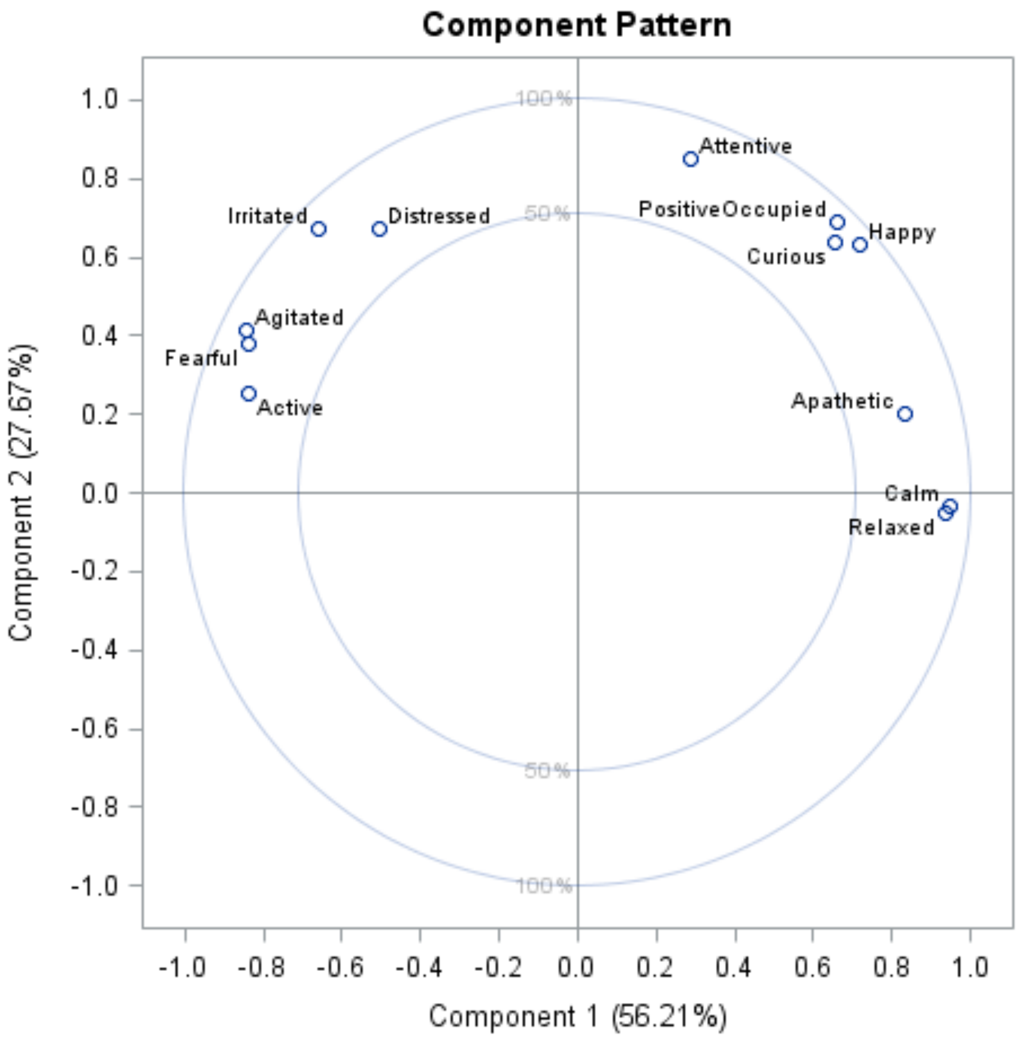

Figure 5. Component pattern plot based on correlations of QBA attributes with principal components 1 and 2. Percent within the parentheses is the percentage of variation accounted by that principal component. Variance percentage circles of 50% and 100% indicate percentage of total variance of component 1 or 2.

used QBA method to study emotional state and welfare for dairy buffaloes (Napolitano et al., 2012), social behavior in dairy cows (Rousing and Wemelsfelder, 2006), and temperament of Nellore cattle (Sant'Anna and Paranhos da Costa; 2013). Across these studies, QBA methods have shown the ability to capture and identify behavioral variance among animals. In this project, TI accounts for 56.21% total variation of the dataset, which is higher than 49.47% reported by Sant'Anna and Paranhos da Costa (2013). This difference may indicate QBA method is more suitable for temperament study of *Bos taurus* (this project) than *Bos indicus* (Sant'Anna and Paranhos da Costa; 2013), however, further study will be necessary considering the sample size difference in this project compared to study of Sant'Anna and Paranhos da Costa (2013).

Statistical modeling

Descriptive statistics. Tendency and variability of temperament measurements across traits (TS, DS, TI, SSD and CVSSD) are reported in Table 10. Comparing the tendency (mean ± SD) and range (min, max) of the data for each year and across two years, all temperament measurements show relatively low scores, even though there is a large variation. For TS and DS, lower scores are referencing better or calmer temperaments, as defined by the scoring methods. The values of TI, SSD, and CVSSD were also within range of what would be expected if they were measuring similar attributes as TS and DS. As our hypothesis is low values of SSD and CVSSD are associated with calm animals, all these relatively low scores across traits indicate animals in this study have relatively calm temperament.

Final model of temperament measurements. Fixed effects, such as date of evaluation, sex and breed types, along with a fixed covariate of sequence nested within date of evaluation were evaluated for significance ($P \leq 0.05$) in SAS for all traits, where the summary P-value table is reported in Tables 11 and 12. In all cases, animal was treated as a random effect using the unstructured variance-covariance type and adjusting the denominator degrees of freedom using Kenward-Roger procedure in SAS. Breed type of the calves was not a significant effect across all traits ($P \geq 0.061$). Although some traits had tendencies ($P \leq 0.100$), further investigation showed that much of this was driven by dam breed type and age, rather than true breed effects, therefore this effect was not included in the final model for this project.

Table 10. Descriptive statistics of temperament scores using TS, DS, TI, SSD and CVSSD measures[1]

	2014			2015			Overall		
Trait	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**
TS	1.799 ± 0.710	1.000	4.000	1.968 ± 0.725	1.000	4.750	1.879 ± 0.722	1.000	4.750
DS	1.825 ± 0.581	1.000	4.5	1.912 ± 0.499	1.000	4.500	1.866 ± 0.545	1.000	4.500
TI	1.572 ± 1.575	-5.020	4.730	-1.741 ± 2.393	-9.260	3.66	0.002 ± 2.599	-9.260	4.730
SSD	46.183 ± 24.409	5.440	119.090	31.592 ± 21.614	1.150	130.310	39.267 ± 24.234	1.150	130.310
CVSSD	0.114 ± 0.063	0.012	0.313	0.072 ± 0.050	0.003	0.263	0.094 ± 0.061	0.003	0.313

[1] TS: temperament score, DS: docility score, TI: temperament index, SSD: standard deviation of four-platform standing scale, CVSSD: coefficient of variation based on the SSD.

Table 11. *P*-values of breed type, date of evaluation, sex and sequence nested within date of evaluation across DS, TS, TI, SSD and CVSSD[1]

Variables	**DS**	**TS**	**TI**	**SSD**	**CVSSD**
Breed type	0.061	0.214	0.177	0.399	0.554
Date of evaluation	<0.0001	0.001	0.214	0.019	0.321
Sex	0.846	0.073	0.012	0.012	0.052
Sequence (date of evaluation)	<0.0001	<0.0001	<0.0001	0.191	0.045

[1] DS: docility score, TS: temperament score, TI: temperament index, SSD: standard deviation of four-platform standing scale data, CVSSD: coefficient of variation based on SSD. *P-value* > 0.05 is non-significant.

Table 12. P-values of breed type, date of evaluation, sex and sequence nested within date of evaluation across QBA attributes[1]

QBA attributes	Breed type	Date of evaluation	Sex	Sequence (date of evaluation)
Active	0.543	<0.0001	0.020	<0.0001
Relaxed	0.069	<0.0001	0.058	<0.0001
Fearful	0.492	<0.0001	0.032	<0.0001
Agitated	0.493	<0.0001	0.134	<0.0001
Calm	0.073	<0.0001	0.021	<0.0001
Attentive	0.329	<0.0001	0.037	<0.0001
Positively occupied	0.193	<0.0001	0.200	<0.0001
Curious	0.653	<0.0001	0.168	<0.0001
Irritated	0.258	0.146	0.023	<0.0001
Apathetic	0.302	<0.0001	0.021	<0.0001
Happy	0.088	<0.0001	0.038	<0.0001
Distressed	0.300	<0.0001	0.005	<0.0001

[1] QBA refers to Qualitative Behavior Assessments. *P-value*> 0.05 is non-significant.

Date of evaluation and sex showed significance across most traits ($P \leq 0.05$, n = 14), however some traits did not show these effects as significant (n = 10). For example, modeling date of evaluation for TI ($P = 0.214$), QBA attribute of irritated ($P = 0.146$), and CVSSD ($P = 0.321$) were not significant. Similarly, sex effect was not significant for DS ($P = 0.846$), TS ($P = 0.073$), QBA attribute of agitated ($P = 0.134$), and positively occupied ($P = 0.200$). Previous literature, however, has shown that date of evaluation and sex of the animal can influence temperament scores (Hoppe et al., 2010; Riley et al., 2014), therefore these factors were included in all models as a blocking factor, regardless of significance. The least squares means comparison of date of evaluation and sex for DS, TS, TI, SSD, CVSSD and QBA attributes are reported in Table 13 and 14. These significant differences between date of evaluation across most traits are consistent with results of Hulsman Hanna et al. (2014). In their study, temperament scoring pen nested within birth year - season combinations, where season effect is similar with effect of date of evaluation in this project, was reported to be significant for

Table 13. Least squares means and standard errors of date of evaluation fixed effect for traits of TS, DS, TI, SSD, CVSSD and QBA attributes[1]

Traits	Date of evaluation[2]			
	1	2	3	4
TS	7.564 ± 3.713^{a}	7.753 ± 3.744^{a}	8.270 ± 3.997^{a}	8.170 ± 3.977^{a}
DS	1.975 ± 0.037^{a}	1.695 ± 0.036^{b}	1.987 ± 0.039^{a}	1.827 ± 0.038^{b}
Active	214.750 ± 95.588^{b}	210.080 ± 96.370^{c}	239.550 ± 102.900^{a}	236.030 ± 102.380^{a}
Relaxed	85.967 ± 1.624^{a}	90.976 ± 1.575^{a}	57.312 ± 1.719^{b}	54.484 ± 1.663^{b}
Fearful	16.980 ± 0.866^{b}	14.005 ± 0.840^{b}	24.001 ± 0.917^{a}	22.343 ± 0.887^{a}
Agitated	22.760 ± 1.198^{b}	21.023 ± 1.162^{b}	30.779 ± 1.268^{a}	31.380 ± 1.227^{a}
Calm	93.616 ± 1.693^{a}	94.604 ± 1.642^{a}	58.337 ± 1.792^{b}	60.593 ± 1.734^{b}
Attentive	209.500± 66.173^{a}	203.520 ± 66.714^{b}	182.670 ± 71.235^{c}	181.330 ± 70.874^{c}
Positively occupied	57.244 ± 0.611^{a}	47.287 ± 0.593^{b}	14.743 ± 0.647^{c}	14.525 ± 0.626^{c}
Curious	54.705 ± 0.833^{a}	47.678 ± 0.808^{b}	14.286 ± 0.881^{c}	13.697 ± 0.857^{c}
Irritated	30.704 ± 124.240^{a}	22.987 ± 125.250^{a}	31.082 ± 133.740^{a}	20.667 ± 133.060^{a}
Apathetic	-124.330 ± 62.845^{a}	-129.830 ± 63.359^{b}	-167.400 ± 67.652^{d}	-162.060 ± 67.310^{c}
Happy	61.180 ± 0.711^{a}	54.269 ± 0.689^{b}	11.854 ± 0.752^{c}	6.227 ± 0.728^{d}
Distressed	19.179 ± 0.783^{a}	11.461 ± 0.760^{b}	17.774 ± 0.829^{a}	7.889 ± 0.802^{c}
TI	-1.346 ± 14.517^{a}	-1.245 ± 14.635^{a}	-4.952 ± 15.627^{a}	-4.568 ± 15.548^{a}
SSD	307.960 ± 112.620^{b}	315.710 ± 113.540^{a}	317.750 ± 121.230^{ab}	312.780 ± 120.620^{ab}
CVSSD	0.0528 ± 0.453^{a}	0.069 ± 0.457^{a}	0.017 ± 0.487^{a}	0.012 ± 0.485^{a}

[1] TS: temperament score, DS: docility score, TI: temperament index, SSD: standard deviation of four-platform standing scale, CVSSD: coefficient of variation based on the SSD, QBA: Qualitative Behavior Assessment.

[2] Date of evaluation 1, 2, 3 and 4 refer to October 6 and 7, 2014 and September 29 and 30, 2015, respectively.

[a-d] Different superscript letters within a row are significantly different ($P < 0.05$).

temperament scores. Significant and numerical differences between heifers and steers (Table 14) were supported by previous studies (e.g., Riley et al., 2014), where heifers were found to have significantly higher temperament mean scores (i.e., be more excitable) than steers. The interaction between date of evaluation and sex was non-significant (P > 0.10) across most traits, except for TS (P = 0.041) and QBA attribute of positively occupied (P = 0.092; tendency). However, pairwise comparisons of the least squares means for this interaction when modeling TS were all non-significant (P ≥ 0.051), indicating a linear contrast may be significant. This was considered to not be an important interaction for this study, therefore, the interaction between

Table 14. Least squares means and standard errors of sex fixed effect for traits of TS, DS, TI, SSD, CVSSD and QBA attributes[1]

Traits	Sex	
	Heifer	Steer
TS	7.985 ± 3.855[a]	7.894 ± 3.860[a]
DS	1.874 ± 0.027[a]	1.867 ± 0.025[a]
Active	226.650 ± 99.247[a]	223.560 ± 99.363[b]
Relaxed	70.622 ± 1.207[a]	73.748 ± 1.123[a]
Fearful	20.278 ± 0.644[a]	18.387 ± 0.599[b]
Agitated	27.399 ± 0.891[a]	25.572 ± 0.829[a]
Calm	74.796 ± 1.258[b]	78.779 ± 1.171[a]
Attentive	195.240 ± 68.706[a]	193.270 ± 68.786[b]
Positively occupied	33.052 ± 0.454[a]	33.847 ± 0.423[a]
Curious	32.008 ± 0.619[a]	33.174 ± 0.576[a]
Irritated	27.591 ± 129.000[a]	25.129 ± 129.150[b]
Apathetic	-147.010 ± 65.250[b]	-144.800 ± 65.326[a]
Happy	32.631 ± 0.528[b]	34.134 ± 0.491[a]
Distressed	15.203 ± 0.582[a]	12.949 ± 0.542[b]
TI	-3.202 ± 15.073[b]	-2.853 ± 15.090[a]
SSD	310.880 ± 116.930[b]	316.220 ± 117.060[a]
CVSSD	0.034 ± 0.470[a]	0.042 ± 0.470[a]

[1] TS: temperament score, DS: docility score, TI: temperament index, SSD: standard deviation of four-platform standing scale, CVSSD: coefficient of variation based on the SSD, QBA: Qualitative Behavior Assessment.

[a-d] Different superscript letters within a row are significantly different ($P < 0.05$).

date of evaluation and sex was dropped from the final model to keep a similar final model across all traits. As additional years of data are added, however, this interaction should be investigated further.

Sequence nested within date of evaluation was included as a fixed covariate for all traits and was found to be significant (P < 0.045) across 16 traits. The only exception was for SSD (P = 0.191). Although not well proven in literature, there is often concern that sequence of evaluation may account for genetic variation of temperament due to certain behavioral attributes influencing whether an animal willingly goes through the working area or not. Therefore, even though sequence nested within date of evaluation was a significant effect for almost all traits, it was not included for breeding value estimation or in calculating genetic correlations in ASReml to avoid removing genetic variation. The final model used for all traits included date of evaluation (n = 4), sex (n = 2), and animal as a random effect.

Characterization of QBA measurements. The score plot (Figure 6) generated with QBA scores of 787 calves against PC1 and PC2 scores was used to classify cattle in this project into four temperament groups based on the graph's quadrants, similar to Sant'Anna and Paranhos da Costa (2013). Four temperament groups included: group I located in the first quadrant (i.e., positive scores for PC1 and PC2), group II located in the second quadrant (i.e., positive PC1

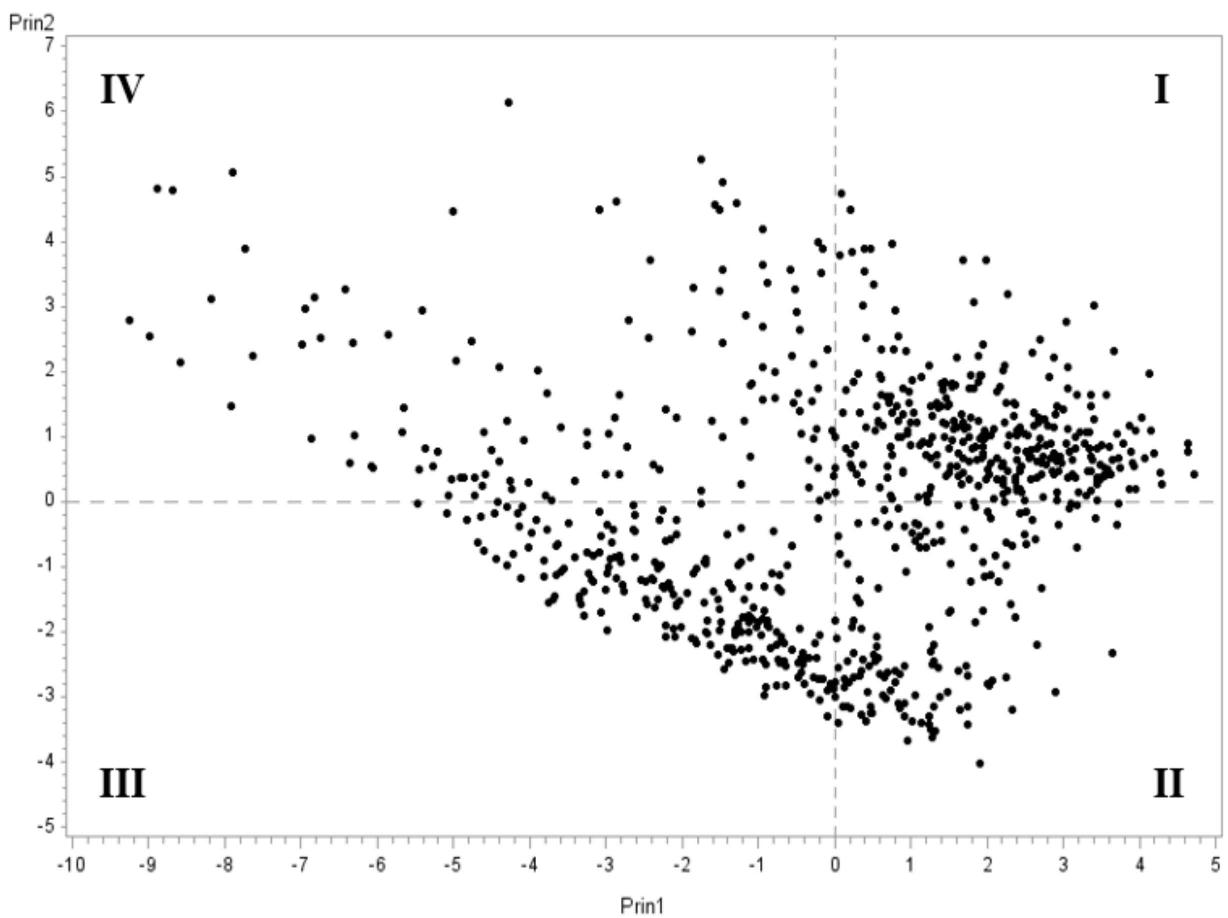

Figure 6. Component score plot of the first two principal components (PC1 and PC2) for each animal (black dot). Quadrants are indicated by roman numeral of 1 through 4.

score and negative PC2 score), group III located in the third quadrant (i.e., negative scores for PC1 and PC2), and group IV located in the fourth quadrant (i.e., negative PC1 score and positive PC2 score).

Using the final model, temperament group was fitted as a fixed effect for each QBA attribute and least square means of each group are reported in Table 15. The four temperament groups show significant differences across all QBA attributes ($P < 0.0001$). Attributes of active, fearful and agitated had the smallest score in temperament group II, increased gradually by group I, III, then IV. On the other hand, attributes of calm and relaxed had the largest scores in temperament group II, decreased gradually by group I, III, then IV. Attributes of irritated and distressed have largest scores in group IV than other groups, and temperament scores for

Table 15. Least squares means and standard errors of qualitative behavior assessment (QBA) attributes according to the four temperament groups (I, II, III and IV)[1]

QBA attribute	Temperament group			
	I	II	III	IV
Active	120.500 ± 84.68^{c}	107.590 ± 84.754^{d}	132 ± 84.545^{b}	150.74 ± 84.629^{a}
Relaxed	82.418 ± 1.470^{b}	95.689 ± 1.542^{a}	59.322 ± 1.613^{c}	42.727 ± 1.550^{d}
Fearful	16.419 ± 77.951^{b}	5.748 ± 78.019^{c}	16.890 ± 77.825^{b}	36.605 ± 77.903^{a}
Agitated	23.270 ± 1.044^{b}	9.887 ± 1.095^{c}	26.283 ± 1.145^{b}	54.137 ± 1.100^{a}
Calm	96.627 ± 141.090^{b}	111.300 ± 141.22^{a}	71.415 ± 140.870^{c}	54.373 ± 141.010^{d}
Attentive	163.340 ± 64.871^{b}	147.150 ± 64.928^{d}	155.300 ± 64.767^{c}	169.140 ± 64.832^{a}
Positively occupied	39.452 ± 0.720^{a}	33.492 ± 0.755^{b}	28.231 ± 0.790^{c}	28.364 ± 0.759^{c}
Curious	38.750 ± 1.015^{a}	31.829 ± 1.065^{b}	28.176 ± 1.114^{c}	26.670 ± 1.070^{c}
Irritated	19.302 ± 0.910^{b}	7.478 ± 0.955^{c}	18.229 ± 0.999^{b}	46.548 ± 0.960^{a}
Apathetic	-86.651 ± 56.377^{a}	-83.418 ± 56.427^{a}	-96.994 ± 56.288^{b}	-106.940 ± 56.344^{c}
Happy	77.897 ± 58.103^{a}	69.983 ± 58.154^{b}	64.606 ± 58.010^{c}	60.127 ± 58.068^{d}
Distressed	12.644 ± 0.789^{b}	6.885 ± 0.827^{c}	11.681 ± 0.866^{b}	30.212 ± 0.832^{a}

[1] Four temperament groups were created based on the graphic quadrants, group I, II, III and IV refer to first quadrant, second quadrant, third quadrant and fourth quadrant, respectively.
[a-d] Different superscript letters within a row are significantly different ($P < 0.05$).

attributes of happy, curious and positively occupied are similar in group I and II, which are larger than the other two groups. Due to this, temperament (i.e., agitation and active) tends to improve in the specified order (i.e., IV > III > I > II) and these groups were named accordingly with very bad temperament, bad temperament, good temperament and very good temperament.

Similarly, temperament group was fitted in the final model for TS, DS, SSD and CVSSD, where least squares means are reported in Table 16. Temperament groups show significant differences for TS ($P < 0.0001$), DS ($P = 0.0102$), SSD ($P = 0.0013$) and CVSSD ($P = 0.0024$). Both TS, SSD and CVSSD have the smallest scores in group II and largest scores in group IV (Table 16). On the other hand, DS has the smallest scores in group III, followed closely by group II, but still has the largest scores in group IV. Generally, within four temperament groups, temperament scores of these four methods increase in the same direction with QBA attributes correlated with agitation and active (i.e., II < I < III < IV), although some variation exists.

Table 16. Least squares means and standard errors of TS, DS, SSD and CVSSD according to the four temperament groups (I, II, III and IV)[1]

	Temperament group			
Traits	**I**	**II**	**III**	**IV**
TS	5.317 ± 3.133^{c}	5.082 ± 3.136^{d}	5.653 ± 3.128^{b}	6.602 ± 3.132^{a}
DS	1.890 ± 0.046^{ab}	1.815 ± 0.049^{b}	1.800 ± 0.051^{b}	2.017 ± 0.049^{a}
SSD	297.990 ± 117.980^{ab}	292.170 ± 118.080^{b}	295.380 ± 117.790^{b}	304.300 ± 117.910^{a}
CVSSD	-0.021 ± 0.433^{ab}	-0.033 ± 0.433^{b}	-0.027 ± 0.432^{b}	-0.005 ± 0.432^{a}

[1] TS refers to temperament score. DS refers to docility score. SSD refers to standard deviation of total weight measured on four-platform standing scale. CVSSD refers to coefficient of variation of standard deviation of total weight measured on four-platform standing scale. Four temperament groups were created based on the graphic quadrants, group I, II, III and IV refer to first quadrant, second quadrant, third quadrant and fourth quadrant, respectively.
[a-d] Different superscript letters within a row are significantly different ($P < 0.05$).

Temperament groups characterized in this project based on QBA measurements against PC1 (TI) and PC2 are different with results from Sant'Anna and Paranhos da Costa (2013), which reported temperament (i.e., agitation and active) increases gradually in a different order (i.e., I > II > III > IV). These differences could be due to the breed differences between *Bos taurus* in this project and *Bos indicus* used by Sant'Anna and Paranhos da Costa (2013), which was reported by other studies (e.g., Buchenauer, 1999; Burrow, 2001). Additionally, number of evaluators and sample size differences between their study and the current study may also contribute some variation, leading to the trend of the TI differing.

Overall, characteristics of temperament in each temperament group characterized within dimension of PC1 (TI) and PC2 show consistency between QBA measurements and other methods (i.e., TS, DS and FPSS measurements). This consistency suggests QBA attributes may capture similar characteristics of temperament with TS and DS, as well as potential objective method of FPSS measurements, which was stated by Wemelsfelder et al. (2001). It may also provide a support for the validity of TI as an indicator for QBA attributes, as well as indicate what attributes were captured by FPSS measures.

Characterization of TI, SSD, and CVSSD in measuring temperament. Comparison between TI and traditional subjective measurements (i.e., TS and DS) indicates TI is negatively correlated to TS (Pearson $\hat{\rho}$ = -0.694, Spearman Rank r = -0.689) and DS (Pearson $\hat{\rho}$ = -0.235, Spearman Rank r = -0.203). This suggests that cattle with higher TI (calm or relaxed) will have lower TS (good temperament) and generally lower DS (good temperament). To verify these correlations, each subjective method (i.e., DS and TS) was included in the final model as a fixed effect for TI independently based on their new category (see Table 5), where least squares means are reported in Table 17. For TS, the least squares means of TI for each category were significantly different with each other and support the negative correlation assumptions. The DS scale had a similar trend as TS with TI, however with the exception of animals with a score of 5 for DS (Table 17). Only one animal was assigned into category 5 of DS in this study, therefore, biasing the differences seen between the other 4 scores.

Table 17. Least squares means and standard errors of temperament index (TI) according to the category of temperament score (TS) and docility score (DS) assigned

Score	TS	DS
1	1.688 ± 0.09^{a}	-5.968 ± 12.994^{a}
2	-0.007 ± 0.061^{b}	-6.530 ± 13.004^{b}
3	-	-6.943 ± 12.999^{b}
4	-2.627 ± 0.106^{c}	-9.407 ± 13.052^{c}
5	-6.512 ± 0.730^{d}	-7.666 ± 13.119^{abc}

[a-d] Different superscript letters within the column are significantly different ($P < 0.05$).

Generally, least squares means of TI decrease with the increasing TS and DS scores (smaller score is considered as good temperament). This tendency of measuring temperament is consisted with the negative correlation, as well as the descriptive statistics in Table 10, which suggests TI can measure similarities of temperament (i.e., opposite direction) with two subjective methods (i.e., TS and DS). However, this result is quite different with results reported by Sant'Anna and Paranhos da Costa (2013), which showed that TI and TS trended in the same direction.

Least squares means for FPSS measures (i.e., SSD and CVSSD) using the two subjective measurements (i.e., TS and DS) in final model independently are reported in Tables 18 and 19. For both SSD and CVSSD, as TS and DS scores increase, so did the least squares means of SSD and CVSSD. The only exception, similar to TI is with DS score of 5, however the same issue of sample size is driving the discrepancy in the trend. These relationships indicate the general trend

Table 18. Least squares means and standard errors of SSD[1] according to the category of temperament score (TS) and docility score (DS)

Score	TS	DS
1	271.900 ± 119.200[c]	322.040 ± 114.530[b]
2	276.980 ± 119.120[b]	328.110 ± 114.600[ab]
3	-	333.240 ± 114.570[a]
4	283.670 ± 119.000[a]	348.080 ± 115.140[a]
5	289.140 ± 119.540[abc]	314.120 ± 116.130[ab]

[1] SSD refers to standard deviation of total weight measured on four-platform standing scale.
[a-d] Different superscript letters within the column are significantly different ($P < 0.05$).
Temperament score (TS) includes 1 to 5 categories, where category 1 indicates animal walks slowly and in close proximity to the evaluator, and an animal with category 5 runs, jumps, or tries to attack the evaluator during the assessment. Category 3 was excluded to avoid having an intermediate score.
Docility score (DS) uses 1 to 6 categories, where category 1 indicates a docile, easily handled animal, and category 6 indicates a very aggressive wild animal. Category 6 was not included in the table as no animal was scored into category 6 in this study.

Table 19. Least squares means and standard errors of CVSSD[1] according to the category of temperament score (TS) and docility score (DS)

Score	TS	DS
1	-0.114 ± 0.391[c]	0.077 ± 0.005[b]
2	-0.100 ± 0.391[b]	0.093 ± 0.002[a]
3		0.104 ± 0.006[a]
4	-0.084 ± 0.391[a]	0.139 ± 0.019[a]
5	-0.074 ± 0.391[abc]	0.062 ± 0.040[ab]

[1] CVSSD refers to coefficient of variation of standard deviation of total weight measured on four-platform standing scale.
[a-d] Different superscript letters within the column are significantly different ($P < 0.05$).
Temperament score (TS) includes 1 to 5 categories, where category 1 indicates animal walks slowly and in close proximity to the evaluator, and an animal with category 5 runs, jumps, or tries to attack the evaluator during the assessment. Category 3 was excluded to avoid having an intermediate score.
Docility score (DS) uses 1 to 6 categories, where category 1 indicates a docile, easily handled animal, and category 6 indicates a very aggressive wild animal. Category 6 was not included in the table as no animal was scored into category 6 in this study.

of each trait with each other on a phenotypic scale, but it is still unknown what type of genetic correlation exists. The phenotypic relationship shown, however, supports our hypothesis that more temperamental animals will shift their weight more often over time, which may provide a support for the validity of using FPSS measurements as an indicator of temperament, given the higher FPSS measurements are according to more weight shift on the scale over time (bad temperament). A similar objective measurement (i.e., a movement-measuring device) was developed by Stookey et al. (1994), which measures temperament by capturing the number of times an animal moved on the scale.

Relationship of FPSS measures with other temperament indicators

Phenotypic correlation coefficients. The phenotypic correlations among FPSS measures and three subjective measurements (TS, DS and TI) are summarized in Table 20. Correlation coefficients between traits across two methods (i.e., Pearson and Spearman Rank) are very similar, which is expected for this data. Furthermore, SSD and CVSSD were very highly correlated with each other, which was also expected (Table 20). Significant correlations were

Table 20. Pearson and Spearman rank correlation coefficients between measures of temperament[1]

	DS	**TS**	**TI**	**SSD**	**CVSSD**
DS		0.156	-0.203	0.118	0.110
TS	0.189		-0.689	0.132	0.124
TI	-0.235	-0.694		0.087	0.106
SSD	0.103	0.144	0.071		0.973
CVSSD	0.089	0.137	0.087	0.957	

[1] All reported correlation coefficients are significant ($P \leq 0.05$). Coefficients below the diagonal indicate Pearson correlation coefficients, and Spearman rank correlation coefficients are above the diagonal. DS: docility score, TS: temperament score, TI: temperament index, SSD: standard deviation of four-platform standing scale, CVSSD: coefficient of variation based on the SSD.

found between SSD and DS, TS, and TI, which ranged from 0.071 to 0.144 across Pearson and Spearman Ranking correlation coefficients. Similarly, significant correlations of CVSSD with DS, TS, and TI ranged from 0.087 to 0.137, which was low. High correlation was found between TI and TS across Pearson and Spearman rank correlations.

The correlation coefficients of FPSS measurements with each of the 12 QBA attributes are shown in Table 21. Correlation coefficients between traits calculated by Pearson and Spearman rank correlation show similar results, which is as expected (Table 21). Correlation coefficients of FPSS measurements for QBA attributes of active, relaxed, fearful, agitated, calm and apathetic were low or non-significant, where they ranged from -0.006 to 0.140. Correlation coefficients between FPSS measurements and the other 6 QBA attributes have higher linear relationships, where they ranged from 0.144 to 0.299.

Table 21. Pearson ($\hat{\rho}$) and Spearman Rank (r) correlation coefficients for SSD and CVSSD with 12 Qualitative Behavior Assessment (QBA) attributes[1]

	SSD		**CVSSD**	
QBA attributes	$\hat{\rho}$	r	$\hat{\rho}$	r
Active	0.006	0.014	-0.006	0.005
Relaxed	0.065	0.055	0.077	0.069
Fearful	0.031	0.033	0.038	0.038
Agitated	0.071	0.104	0.071	0.105
Calm	0.066	0.051	0.078	0.062
Attentive	0.272	0.277	0.294	0.299
Positively occupied	0.242	0.232	0.275	0.262
Curious	0.224	0.223	0.249	0.250
Irritated	0.179	0.201	0.188	0.211
Apathetic	0.085	0.102	0.123	0.140
Happy	0.257	0.228	0.285	0.252
Distressed	0.144	0.195	0.162	0.209

[1] Correlation coefficients > 0.069 indicates significant correlation. SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD

The correlations of FPSS measurements with DS, TS, TI and most QBA attributes are statistically significant, however, these linear correlation coefficients are not very strong. This may indicate the objective measures from the FPSS are not measuring similar attributes in the subjective measures as originally thought, however the trends shown in Tables 17 and 18 suggest that a real relationship exists to some extent. Burrow and Corbet (1999) reported a low to moderate phenotypic correlation between objective flight speed and crush score, and Schwartzkopf-Genswein et al. (2011) found a low phenotypic correlation between objective method of flight time and subjective methods of visual score (i.e., restraint test), which supports objective measures may naturally have a lower correlation with subjective measures. Additionally, evaluator bias or errors in DS, TS, TI and QBA attributes may reduce correlation, which has been reported before (Bovin et al., 1992). Burrow and Corbet (1999) investigated whether weight and age were significant regression parameters for subjective measurements of visual flight speed and crush score. They found that weight was a significant factor for these scoring methods, indicating that weight could be biasing the evaluator's interpretation on these scales. A similar relationship could exist with these cattle and would need to be investigated to verify.

The correlation between FPSS measurements and QBA attributes was initially hypothesized that the larger FPSS measurements would indicate more movement, and, therefore attributes such as active, agitated, irritated, and distressed were thought to potentially be linearly correlated in the same direction as FPSS measurements. Some level of correlation did exist in the same direction between irritated and distressed with SSD and CVSSD, however the correlations of positively occupied, curious, and happy had stronger relationship and in opposite direction than hypothesized.

Based on these results, no strong linear phenotypic correlations are found between FPSS measurements and other subjective measurements. Furthermore, scatterplots between each pair of traits were investigated (figures not included) and indicated no quadratic or cubic relationships exist. The significant linear correlations across all these measurements do indicate some similar phenotypic characteristics of temperament were captured by both FPSS measures and other subjective measurements, which may provide a support for using the FPSS as an indicator to measure temperament in cattle.

EBV correlation coefficients. Estimated breeding values (EBV) were generated using a traditional animal model in univariate analysis. Correlation coefficients calculated with Pearson and Spearman Rank methods between the EBV of DS, TS, TI, FPSS measurements and QBA attributes are reported in Table 22 and 23. These correlation coefficients provide indicators of genetic trends with each trait outside of a bivariate analysis. The correlation coefficients between traits across two methods (i.e., Pearson and Spearman Rank) show similar results as expected. Non-significant correlation coefficients ($P \leq 0.05$) appears between SSD and all subjective measurements (i.e., DS, TS, TI and QBA measurements). Correlation coefficients of CVSSD with DS, TS, and TI are slight, but statistically significant (Table 22). Similarly, statistically significant correlation coefficients appear between CVSSD and QBA attributes, except for attributes of attentive, positively occupied, apathetic and happy (Table 23). Strong negative correlation appears between TI and TS, where the negative relationship was expected given the trend of TI compared to TS and DS. Furthermore, non-significant correlation appears between SSD and CVSSD across two methods, which was not expected as these two measures should show high correlation with the EBV considering how we calculated them. This non-significant correlation may due to the different scale of the two measures, as well as sample size influence.

Table 22. Pearson and Spearman Rank correlation coefficients between estimated breeding values (EBV) of temperament measures[1]

	DS	TS	TI	SSD	CVSSD
DS		0.232	-0.311	0.049	0.230
TS	0.259		-0.748	-0.0097	0.172
TI	-0.361	-0.763		0.018	-0.119
SSD	0.035	-0.016	0.017		0.028
CVSSD	0.234	0.167	-0.107	0.050	

[1] Absolute value of correlation coefficients > 0.049 indicates a significant correlation. Coefficients below the diagonal indicate Pearson correlation coefficients, and Spearman rank correlation coefficients are above the diagonal. DS: docility score, TS: temperament score, TI: temperament index, SSD: standard deviation of four-platform standing scale, CVSSD: coefficient of variation based on the SSD. EBV refers to estimates of breeding value of each trait from univariate analysis of a traditional animal model.

Table 23. Pearson ($\hat{\rho}$) and Spearman Rank (r) correlation coefficients between estimated breeding values (EBV) of SSD and CVSSD with QBA attributes[1]

	SSD		CVSSD	
QBA attributes	$\hat{\rho}$	r	$\hat{\rho}$	r
Active	-0.022	-0.035	0.109	0.117
Relaxed	0.001	0.010	-0.097	-0.098
Fearful	-0.032	-0.021	0.161	0.157
Agitated	-0.031	-0.0284	0.166	0.183
Calm	0.027	0.041	-0.101	-0.117
Attentive	-0.010	-0.010	0.049	0.066
Positively occupied	0.003	0.016	0.078	0.046
Curious	-0.014	-0.018	0.119	0.077
Irritated	0.007	0.011	0.166	0.174
Apathetic	0.016	0.010	-0.057	-0.071
Happy	-0.017	-0.006	0.084	0.048
Distressed	0.017	0.006	0.190	0.206

[1] Absolute value of correlation coefficients > 0.071 indicates significant correlation. SSD: standard deviation of four-platform standing scale, CVSSD: coefficient of variation based on the SSD. EBV refers to estimates of breeding value of each trait from univariate analysis of a traditional animal model.

The statistically non-significant correlations of SSD with DS, TS, TI and QBA attributes may indicate SSD and these subjective measurements capture different characteristics of temperament genetically. Furthermore, there is a concern for SSD measurement in this project, which is the actual weight of the animal may bias the SSD, given that larger animals may naturally have larger SSD, regardless of temperament, which is why CVSSD is also being evaluated. Burrow and Corbet (1999) reported the linear regression of weight is significantly related to objective measurements (i.e., visual flight score and crush score). The correlation coefficients between SSD and DS across the two methods are obviously higher than the correlation coefficients of SSD with other measurements (Table 22 and 23), which may provide a direction for studying the potential effect of weight in a future study. The statistically significant, but not strong correlation coefficients of CVSSD with DS, TS, TI and most QBA attributes suggest this objective measurement and current subjective measurements may capture similar characteristics of temperament genetically, which has been reported by other studies (Burrow and Corbet, 1999; Kadel et al., 2006), where a moderate genetic correlation between flight time and chute score was found. Compared to the non-significant correlation between SSD and all subjective measurements, this suggests CVSSD may capture more similar aspects of temperament genetically with other subjective measurements and is more appropriate to use as an indicator of temperament through the FPSS.

The strong negative correlation between TS and TI based on EBV is consist with phenotypic correlation discussed earlier, which suggests these two methods may measure similar aspects of temperament in both genetic and phenotypic aspects, but in opposite directions for this population. The non-significant correlation coefficient of SSD with CVSSD is not expected given their known relationship, however, it is recognized that the sample size is still relatively low in this study, which may lead to lower accuracy in EBV predictions across traits. Due to this, it is likely that some of the true relationship between these traits are being lost due to lack of precision in estimates.

Generally, these results indicated some significantly linear correlation exist between FPSS measurements and other subjective measurements. Furthermore, scatterplot with EBV between traits do not show any quadratic or cubic relationships, which indicate that the linear relationship found (significant or not) is the best estimate of their similarities. These correlations provide a preliminary understanding of the genetic associations between FPSS and subjective measurements, and may provide support for the validity of FPSS as an indicator to measure temperament in cattle. However, these correlation coefficients (i.e., EBV and phenotypic aspects) are not strong enough to understand the real correlations between FPSS measurements and other subjective measurements. Due to all of these reasons, bivariate analysis between each pair of traits with a traditional animal model was conducted.

Bivariate analysis in ASReml. Phenotypic and genetic correlations from bivariate analysis and heritability from univariate analysis of DS, TS, TI, FPSS measurements and QBA attributes are reported in Tables 24 and 25. Estimated heritability for DS, TS, TI and FPSS measurements ranged from 0.192 to 0.417. For QBA attributes, estimated heritability ranged from 0.141 to 0.439, except for attentive, which was estimated to be zero. The reason for a zero heritability for the attentive attribute could be due to variation in this attribute being due primarily by epistatic effects, dominance effects, environmental effects, or a combination of these effects. Additionally, this could be due to the cattle population in this project having very small variation for attentive. However, the standard deviation of attentive in phenotypic correlation is not very small compared to other QBA attributes, which indicates population variation for attributes of

Table 24. Estimates of heritability and phenotypic and genetic correlation between measures of temperament[1]

	DS	TS	TI	SSD	CVSSD
DS	0.226 ± 0.109	0.553 ± 0.265	-0.646 ± 0.231	0.549 ± 0.316	0.643 ± 0.301
TS	0.194 ± 0.036	0.405 ± 0.125	-0.737 ± 0.104	0.320 ± 0.268	0.219 ± 0.261
TI	-0.295 ± 0.034	0.089 ± 0.037	0.417 ± 0.119	-0.152 ± 0.276	-0.195 ± 0.257
SSD	0.104 ± 0.036	0.190 ± 0.036	-0.098 ± 0.037	0.192 ± 0.090	0.866 ± 0.060
CVSSD	0.089 ± 0.037	0.185 ± 0.036	-0.091 ± 0.037	0.956 ± 0.003	0.244 ± 0.103

[1] The diagonal elements are estimates of heritability for each trait from univariate analysis in ASReml (Gilmour et al., 2015). Elements above the diagonals are genetic correlations and below the diagonals are phenotypic correlations from bivariate analysis in the same software. DS: docility score, TS: temperament score, TI: temperament index, SSD: standard deviation of four-platform standing scale, CVSSD: coefficient of variation based on the SSD.

Table 25. Estimates of heritability ($\hat{h}^2$) for qualitative behavior assessment (QBA) attributes and phenotypic and genotypic correlation coefficients of those attributes with SSD and CVSSD[1]

		SSD		CVSSD	
QBA attributes	$\hat{h}^2$	Phenotypic[2]	Genetic[3]	Phenotypic[2]	Genetic[3]
Active	0.353 ± 0.120	0.091 ± 0.037	0.331 ± 0.280	0.083 ± 0.037	0.325 ± 0.262
Relaxed	0.409 ± 0.121	-0.080 ± 0.037	-0.097 ± 0.285	-0.076 ± 0.037	-0.129 ± 0.267
Fearful	0.280 ± 0.113	0.105 ± 0.036	0.154 ± 0.318	0.115 ± 0.0366	0.268 ± 0.296
Agitated	0.398 ± 0.123	0.147 ± 0.036	0.161 ± 0.286	0.150 ± 0.037	0.242 ± 0.264
Calm	0.439 ± 0.121	-0.083 ± 0.037	-0.131 ± 0.276	-0.080 ± 0.037	-0.211 ± 0.255
Attentive	0	0.140 ± 0.035	-	0.143 ± 0.035	-
Positively occupied	0.155 ± 0.092	0.054 ± 0.036	0.058 ± 0.378	0.077 ± 0.036	0.110 ± 0.361
Curious	0.141 ± 0.088	0.039 ± 0.036	0.242 ± 0.383	0.050 ± 0.036	0.291 ± 0.374
Irritated	0.396 ± 0.119	0.163 ± 0.036	0.121 ± 0.282	0.164 ± 0.036	0.154 ± 0.264
Apathetic	0.294 ± 0.123	-0.100 ± 0.037	-0.309 ± 0.300	-0.069 ± 0.037	-0.222 ± 0.291
Happy	0.163 ± 0.086	0.069 ± 0.036	0.142 ± 0.352	0.084 ± 0.036	0.161 ± 0.337
Distressed	0.292 ± 0.109	0.106 ± 0.036	0.230 ± 0.301	0.114 ± 0.037	0.352 ± 0.281

[1] SSD refers to standard deviation of four-platform standing scale, CVSSD refers to coefficient of variation based on SSD."-" indicates correlation is not available.
[2] Phenotypic refers phenotypic correlation.
[3] Genetic refers to genetic correlation.

attentive exist, but this attribute may have a larger proportion of phenotypic variation due to other effects than additive gene effects. In general, the genetic correlations were a higher degree than phenotypic correlations, where the only exception was between SSD and CVSSD. The genetic and phenotypic correlation coefficients of FPSS measurements with DS, TS, TI and QBA attributes show similar results across SSD and CVSSD. Genetic correlation coefficients of FPSS measurements with DS, TS and TI ranged from slight to large. Phenotypic correlation coefficients of FPSS measurements with DS, TS and TI ranged from trivial to slight and are similar to Pearson correlations reported previously. Furthermore, genetic and phenotypic correlations between SSD and CVSSD are large, indicating a relationship that was originally thought to exist. This large significant genetic correlation between SSD and CVSSD has also supported our hypothesis that the non-significant correlation between SSD and CVSSD with EBV may be due to the different scale of these two measures.

The estimates of heritability of DS and TS (Table 24) are moderate and consistent with previous studies. Hoppe et al. (2010) found the heritability of crush score (DS in this project) for German Angus and Hereford to be 0.15 and 0.33, respectively. The heritability of DS in Angus heifers was reported to be 0.22 by Otterman et al. (2013). Loyd et al. (2011) and Schmidt et al. (2014) reported the heritability of pen score (TS in this project) to be 0.48 and 0.49, respectively. These results suggest a moderate genetic component captured by DS and TS. The estimates of heritability of FPSS measurements (i.e., SSD and CVSSD; Table 24) are considered as moderate given the heritability of some other objective methods reported. Schmidt et al. (2014) and Sant'Anna et al. (2015) reported the heritability of flight speed to be 0.27 and 0.26, respectively, and very similar to the estimate reported in this study. The heritability of a movement - measuring - device (MMD) was estimated to be 0.36 by Schmutz et al. (2001), which is much higher than found here. This is the first study to report the heritability of TI (Table 24), where other subjective measurements have been reported to range from 0.03 to 0.67, and is in line with our current estimate. Haskell et al. (2014) and Burrow (1997) reported a 0.36 heritability for a non-restrained measurement, which is similar to the estimate found for TI in this study. The heritability of QBA attributes ranges from 0.141 to 0.439, and are considered as moderate due to the subjective nature of the method. There are not any previous reports of heritability estimates for QBA attributes in cattle prior to this study. Riley et al. (2014) reported the estimates of heritability for 5 subjectively measured aspects of temperament in cattle (i.e., aggressiveness, nervousness, flightiness, gregariousness and overall temperament) to be 0.51, 0.4, 0.45, 0.49 and 0.47, respectively, which align well with QBA attributes in this study.

Generally, the estimates of heritability for DS, TS, TI, FPSS measurements and QBA attributes, which indicates the proportion of phenotypic variation accounted by additive gene effects, are considered as moderate given these results. These moderate heritability estimates suggest that these measures can be used for selection purposes that may result in moderately fast genetic changes. The relatively large standard errors reported suggest these estimates of heritability are preliminary, however, and may change by increasing sample size. Even so, these preliminary estimates of heritability can provide an understanding for the genetic contribution to the variation of temperament, which can be used for genetic selection purpose. Our population size (n = 787) is closed to preferred sample size (n = 1000) for calculating genuine estimates of heritability, however, parentage testing for an improved pedigree as sire was unknown for some calves would provide stronger estimates in this study. Likewise, standard errors for genetic correlations are relatively large, where a sample size close to or more than 2,000 animals is preferred for genuine estimates of genetic correlation through bivariate analysis. Even so, the estimates of heritability and genetic correlations for TI, QBA attributes and FPSS measurements are the first reported in cattle, and should provide a better understanding of genetic contribution in these measurements. Estimates of heritability of personality dimensions, which is similar with QBA attributes measurements in this study, have been reported to range from 0 to 0.4 (Brent et al., 2014) for other species, such as birds (Bize et al., 2012), sheep (Reale and Festa-Bianchet, 2003) and squirrels (Taylor et al., 2012).

The genetic correlations between 3 subjective measurements (i.e., DS, TS and TI) are all large, which is consist with large correlations between subjective measurements reported by other studies (e.g., Hoppe et al., 2010). The phenotypic correlations between DS, TS and TI ranged from trivial to slight, which is similar with the results reported by Curley et al. (2014). These differences between subjective measurements could be due to the evaluator bias or errors mentioned in early section (i.e., weight would be biasing the evaluator's interpretation), as well as sample size influence in this study. These strong genetic correlations and slight phenotypic correlations suggest these subjective methods are related genetically, but they are not an accurate indicator for each other in real measurement. These results do suggest some similar characteristics of temperament are measured by both of these subjective measurements.

Phenotypic correlation coefficients of FPSS measurements with DS, TS, TI and QBA attributes ranged from trivial to moderate, which show similar trends with results of Pearson and Spearman Rank correlation. Genetic correlation coefficients of FPSS measurements (i.e., SSD and CVSSD) with TS, TI and QBA attributes range from slight to moderate, which is consistent with previous studies. For example, Burrow and Corbet (1999) reported the genetic correlations between flight speed and crush score to be -0.45. These differences between FPSS and other subjective measurements are probably due to the natural difference between subjective and objective methods in measuring temperament (Burrow and Corbet, 1999). Additionally, differences could be due to some level of evaluator errors or bias in subjective measurements, given the nature of subjective measurements (Boivin et al., 1992). The genetic correlations between FPSS measurements (i.e., SSD and CVSSD) and DS are 0.549 and 0.643, respectively, which is larger than the correlations between other subjective and objective measurements reported by previous studies (Burrow and Corbet, 1999; Schwartzkopf-Genswein et al., 2011). These larger genetic correlations may support FPSS measurements can capture some similar characteristics of temperament with subjective measurement of DS.

Generally, these genetic and phenotypic correlations of FPSS measurements with all subjective measurements are enhanced compared to Pearson and Spearman Rank correlation of temperament scores and EBV. This was expected given that bivariate analysis capitalizes on underlying correlations between traits while estimating parameters. Given the large standard errors reported, these estimates are preliminary and may change when additional experimental units are added. However, these results generally show the FPSS measurements do measure some similar characteristics of temperament with other subjective methods, which may provide a support for the validity of using the FPSS as an indicator to measure temperament in cattle. Furthermore, the moderate estimates of heritability of FPSS measurements suggest FPSS could potentially be used as a selection tool for moderately fast genetic gain in temperament improvement. The strong genetic and phenotypic correlations between SSD and CVSSD suggests these two traits are highly correlated and can be used as an indicator for each other, which is expected, given the characteristics of our data. However, within FPSS measurements, CVSSD has a better fit with most of subjective measurements than SSD in both genetic and phenotypic aspects.

Quartile comparison of EBV. Based on EBV rankings (desirable to undesirable) for each trait, quartile assignment and changes across traits are summarized in Tables 26 to 28. The quartile ranking of TI was fixed by using an opposite direction of the original EBV ranking to be consistent with other traits, given TI has shown negative correlations with all other traits. Within these quartile comparisons, 3 quartile changes were considered as significant differences in ranking between traits, 2 quartile changes were considered moderate differences, and 1 quartile change was considered minimal differences. Considering that accuracy of the EBV predicted may still be low, those with 3 quartile changes were considered significant as there would be true indications of re-ranking regardless of accuracy in this study. Quartile comparison of FPSS measurements with DS, TS, TI and QBA attributes show similar results across SSD and CVSSD (Tables 26 to 28), which is expected for the characteristics of our data. No more than 17% of

Table 26. Comparison of percentage of individuals with estimated breeding values that change *n* quartiles between DS, TS, TI, SSD and CVSSD[1]

	Percentage of individuals that changed *n* quartiles			
Trait comparison	0	1	2	3
DS *vs.*TS	32.15%	36.85%	21.85%	9.15%
*vs.*TI	33.54%	39.14%	20.84%	6.48%
*vs.*SSD	31.13%	40.54%	19.82%	8.51%
*vs.*CVSSD	32.02%	39.64%	19.19%	9.15%
TS *vs.*SSD	29.73%	39.77%	22.24%	8.26%
*vs.*CVSSD	30.62%	38.25%	22.62%	8.51%
*vs.*TI	50.83%	39.90%	8.89%	0.38%
SSD *vs.*CVSSD	64.17%	35.32%	0.51%	0.00%
*vs.*TI	28.34%	39.26%	21.98%	10.42%
CVSSD *vs.*TI	27.57%	41.04%	21.22%	10.17%

[1] Percentage was calculated by dividing the number of individuals within that category by the total number of animals (n = 787) and multiplying by 100. The number of quartiles changed was calculated by comparing quartile difference of each animal assigned by different traits between each pair of traits. DS: docility score, TS: temperament score, TI: temperament index, SSD: standard deviation of four-platform standing scale, CVSSD: coefficient of variation based on the SSD.

Table 27. Comparison of percentage of individuals with estimated breeding values that change *n* quartiles between SSD and all qualitative behavior assessment (QBA) attributes[1]

	Percentage of individuals that changed *n* quartiles			
QBA attributes	0	1	2	3
Active	28.79%	38.85%	22.29%	10.06%
Relaxed	22.90%	37.28%	25.06%	14.76%
Fearful	29.43%	35.80%	24.46%	10.32%
Agitated	29.64%	37.79%	23.28%	9.29%
Calm	22.26%	37.28%	25.70%	14.76%
Attentive	26.08%	35.75%	26.34%	11.83%
Positively occupied	23.16%	36.64%	26.34%	13.87%
Curious	23.51%	37.87%	26.94%	11.69%
Irritated	25.86%	41.78%	22.17%	10.19%
Apathetic	24.30%	34.10%	24.68%	16.92%
Happy	23.66%	36.26%	27.86%	12.21%
Distressed	27.64%	38.09%	23.69%	10.57%

[1] Percentage was calculated by dividing the number of individuals within that category by the total number of animals (n = 787) and multiplying by 100. The number of quartiles changed was calculated by comparing quartile difference of each animal assigned by different traits between each pair of traits. SSD: standard deviation of four-platform standing scale.

Table 28. Comparison of percentage of individuals with estimated breeding values that change *n* quartiles between CVSSD and qualitative behavior assessment (QBA) attributes[1]

	Percentage of individuals that changed *n* quartiles			
QBA attributes	0	1	2	3
Active	29.10%	37.36%	23.38%	10.17%
Relaxed	21.60%	35.96%	28.59%	13.85%
Fearful	28.21%	38.75%	24.27%	8.77%
Agitated	28.08%	40.79%	23.13%	8.01%
Calm	22.24%	33.42%	30.75%	13.60%
Attentive	25.92%	37.10%	27.45%	9.53%
Positively occupied	25.29%	35.96%	27.95%	10.80%
Curious	23.63%	36.85%	30.37%	9.15%
Irritated	29.10%	39.52%	22.11%	9.28%
Apathetic	25.16%	34.05%	26.05%	14.74%
Happy	27.06%	33.16%	29.48%	10.29%
Distressed	31.13%	36.09%	23.89%	8.89%

[1] Percentage was calculated by dividing the number of individuals within that category by the total number of animals (n = 787) and multiplying by 100. The number of quartiles changed was calculated by comparing quartile difference of each animal assigned by different traits between each pair of traits. CVSSD: coefficient of variation based on the standard deviation of four-platform standing scale.

animals had significant quartile changes between FPSS measurements and subjective measurements (DS, TS, TI and QBA attributes). Quartile comparison between SSD and CVSSD show 0.51% of animals changed more than 1 quartile, which suggests a strong correlation of ranking in EBV. Furthermore, significant quartile changes between TI with DS and TS are less than 7%, which is lower than other comparisons.

Quartile comparison of EBV can identify the differences between two measurements by comparing how they evaluate and rank animal temperaments, and thereby impact selection response. Higher percentage of significant quartile changes between two measurements indicate these two measurements may evaluate temperament differently, and, therefore, rank animals in different way genetically. Based on this, the moderate and significant quartile changes between FPSS measurements (i.e., SSD and CVSSD) and DS are smaller than others (i.e., TS and TI), which suggest the FPSS measurements and DS measure similar aspects of temperament and would, thereby, have more similar selection impacts compared to the other subjective measures. This result is consistent with the genetic correlations from bivariate analysis. The significant quartile changes of FPSS measurements (i.e., SSD and CVSSD) with other subjective measurements (TS, TI and QBA attributes) are both less than 17%, which suggests FPSS can capture similar characteristics of temperament with these subjective measurements, however some significant re-ranking does occur. Specifically, SSD had the lowest percentage of significant re-ranking with QBA attributes of agitated, followed by active. For CVSSD, the QBA attributes of agitated, followed by distressed, had the lowest percentage of significant re-ranking. In both cases, their similarity in breeding value predictions indicates the FPSS may provide indicators of stress and fear of the animal, which is similar to what exit velocity is thought to capture as well (Curley et al., 2006; Turner et al., 2011). The smaller percentage of quartile changes of TI with DS and TS suggest TI measure similar aspects of temperament with DS and TS given the trend of the traits. This result is consistent with the large genetic correlations found in bivariate analysis. These genetic similarities from quartile comparison show similar trends with the results of bivariate analysis which are expected, given the quartile comparison is comparing EBV of each trait which expected to rank animals in a similar way (i.e., show small percentage of significant changes) if they have high correlations. Generally, results from quartile comparison give support for the genetic and phenotypic correlations obtained from bivariate analysis.

Implications

This study is trying to explore the validity of a four-platform standing scale in the application of measuring temperament, which can provide an objective method for studying temperament in cattle. This potential objective and quantitative measurement is expected to give a better understanding of temperament without evaluator bias, given most traditional measurements are qualitative and based on the observer's rating. With the moderate estimates of heritability, this measurement is expected to allow for moderately fast genetic changes, which could be applied to genetic selection for temperament improvement in production as long as what it changes is well understood. For research purposes, the FPSS measurements could potentially provide a direction for the application and exploration of other movement measuring approaches. The multiple attributes potentially captured by four-platform standing scale could provide information for beef cattle producers to increase their understanding of the actual behavioral attributes of temperament captured by four-platform standing scale, which could be applied as a new objective way to improve selection decisions. In its current state, however, the FPSS is not conducive to beef cattle producer needs as it will not adequately restrain animals like a silencer chute. If, through research, the FPSS proves to be viable objective method for measuring temperament in beef cattle, the scale platform would need to be implemented within a silencer chute framework so that other tasks can also be accomplished by the producer.

Within FPSS measurements, SSD and CVSSD were highly correlated both genetically and phenotypically. However, CVSSD shows better fit with most of other subjective measurements, as well as has larger estimates of heritability than SSD. This indicates CVSSD may be more appropriate to use as an indicator of temperament with the FPSS. Furthermore, it is recognized that the sample size is still relatively low in this study, which can impact the relationships found as more measurements are added. In the future, an increase in sample size and genomic information can help validate the findings of this study for characteristics of FPSS measurements.

CHAPTER 5. GENERAL SUMMARY AND CONCLUSIONS

The correlation coefficients of FPSS measurements with most subjective measurements show statistically significant correlation in both genetic and phenotypic aspects across all three comparison methods. These significant correlations indicate FPSS measurements and these subjective measurements may measure similar characteristics of temperament. Furthermore, the significant correlations between FPSS measurements and most QBA attributes, especially relatively higher correlations with attributes of active, curious, fearful and distressed, suggests FPSS measurements may capture these temperament attributes that are related with excited temperament. The results of quartile comparison between FPSS measurements and some subjective measurements (e.g., TS and DS) showed relatively smaller significant quartile changes (i.e., less than 9%), which provides support for these preliminary conclusions. Temperament index (TI) has shown negative correlations across all other measurements in both genetic and phenotypic aspects. This suggests that TI is associated with subjective measurements, but in the opposite direction for the current dataset.

The heritability of DS, TS, TI, FPSS measurements, and QBA attributes (except for attentive) ranges from 0.1407 to 0.4389, which is moderately heritable and in line with other studies. These moderate heritabilities suggest that these measures can be used for selection purposes and may result in moderately fast genetic changes, given it is understood what is actually being measured. Within FPSS measurements, CVSSD has a larger estimates of heritability and higher correlations with subjective measures than SSD, which suggests CVSSD will result in faster genetic changes and in a similar direction as subjective measures.

It is planned to increase sample size of this project, which will help validate findings reported in this study. Furthermore, genomic information of these cattle included in this research will be combined to get genomic estimates of breeding value (direct genomic values; DGV) to improve our understanding of genetic merit of temperament as well as genomic regions that may be selected for if a measure of the FPSS is used for temperament selection. In the future, if this method is to be implemented for measuring temperament, some improvements of this new quantitative method using the FPSS may be made to make it more applicable for production use considering the cost of it is still expensive. For example, developing a new FPSS that combines some functions of a silencer (i.e., squeeze) chute to make it used widely for both research and production would be worthwhile.

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APPENDIX

Table A1. Least squares means of blood drawn nested within day of evaluation for traits of TS, TI, SSD, CVSSD and QBA attributes[1]

	Day 1		Day 2	
Traits	**Before**	**After**	**Before**	**After**
TS	8.053 ± 5.444[a]	8.233 ± 5.440[a]	8.321 ± 5.484[b]	8.338 ± 5.490[b]
TI	-2.417 ± 15.451[a]	-2.773 ± 15.440[a]	-2.544 ± 15.564[b]	-2.565 ± 15.583[b]
SSD	266.400 ± 185.520[a]	271.530 ± 185.390[a]	274.48 ± 186.89[b]	277.83 ± 187.12[b]
CVSSD	-0.2338 ± 0.556[a]	-0.2214 ± 0.555[a]	-0.219 ± 0.560[b]	-0.210 ± 0.560[b]
Active	219.040 ± 89.522[a]	221.480 ± 89.460[a]	215.660 ± 90.180[b]	216.610 ± 90.290[b]
Relaxed	36.698 ± 172.260[a]	32.341 ± 172.140[a]	38.120 ± 173.530[b]	38.599 ± 173.740[b]
Fearful	16.236 ± 0.884[a]	16.853 ± 0.876[a]	13.216 ± 0.844[b]	14.676 ± 0.858[b]
Agitated	20.463 ± 1.167[a]	24.013 ± 1.156[a]	20.207 ± 1.114[b]	21.459 ± 1.133[b]
Calm	96.251 ± 1.742[a]	91.986 ± 1.726[a]	93.608 ± 1.664[b]	95.226 ± 1.692[b]
Attentive	202.230 ± 87.680[a]	199.260 ± 87.619[a]	194.790 ± 88.324[b]	194.560 ± 88.432[b]
Positively occupied	57.417 ± 0.907[a]	56.119 ± 0.898[a]	46.343 ± 0.866[b]	47.429 ± 0.880[b]
Curious	16.146 ± 132.900[a]	14.329 ± 132.810[a]	7.981 ± 133.880[b]	8.294 ± 134.040[b]
Irritated	63.992 ± 112.430[a]	65.634 ± 112.350[a]	57.103 ± 113.260[b]	58.376 ± 113.390[b]
Apathetic	-57.414 ± 108.690[a]	-57.922 ± 108.620[a]	-63.137 ± 109.490[b]	-62.321 ± 109.630[b]
Happy	62.205 ± 1.195[a]	59.744 ± 1.184[a]	53.719 ± 1.141[b]	54.050 ± 1.160[b]
Distressed	-17.293 ± 91.781[a]	-15.396 ± 91.717[a]	-23.699 ± 92.456[b]	-24.355 ± 92.568[b]

[1] DS: docility score, TS: temperament score, TI: temperament index, SSD: standard deviation of four-platform standing scale data, CVSSD: coefficient of variation based on SSD, QBA: Qualitative Behavior Assessments.

[a-b] Different superscript letters within a row and within a day are significantly different ($P < 0.05$).